SELF-EVALUATION REPORT
APPLIED PHYSICS
2021

UNIVERSITY OF TWENTE.

COLOPHON

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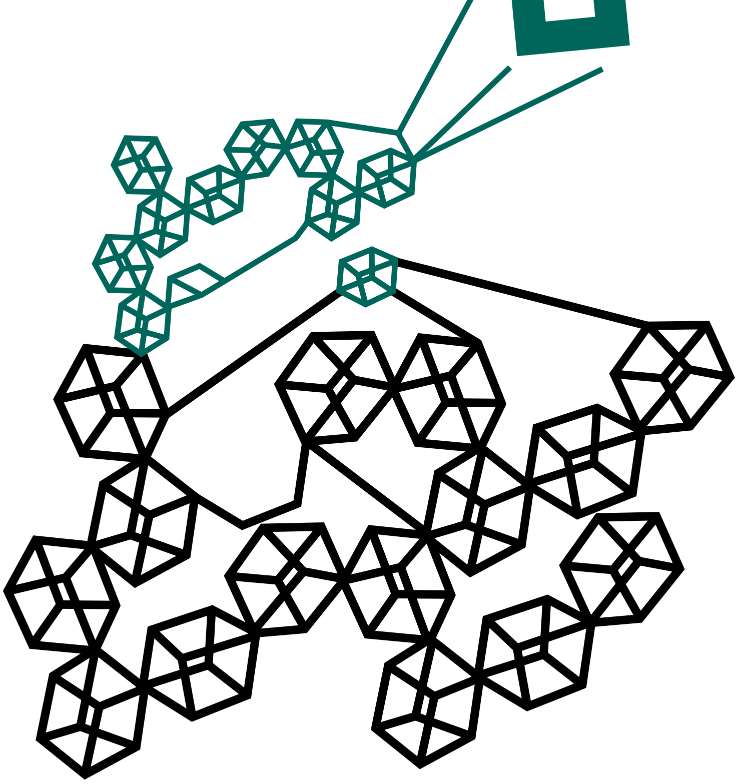

ADMINISTRATIVE DATA

ADMINISTRATIVE DATA BACHELOR'S PROGRAMME

Name	*BSc in Applied Physics (BSc Technische Natuurkunde)*
Orientation and level	*Academic Education, Bachelor*
Study load	*180 EC*
Location at which programmes are delivered	*Enschede, the Netherlands*
Mode of study	*Full-time*
Language	*Dutch*
CROHO registration number	*56962*
Name of institution	*University of Twente*
Status of institution	*Publicly funded*
Result of institutional quality assurance audit	*Positive, 28 April 2020*
Contact person	*E.S. Kooij* *Director of Education* *E: e.s.kooij@utwente.nl* *T: 053-4893106*

ADMINISTRATIVE DATA MASTER'S PROGRAMME

Name	*MSc in Applied Physics*
Orientation and level	*Academic Education, Master*
Study load	*120 EC*
Location at which programmes are delivered	*Enschede, the Netherlands*
Mode of study	*Full-time*
Language	*English*
CROHO registration number	*60436*
Name of institution	*University of Twente*
Status of institution	*Publicly funded*
Result of institutional quality assurance audit	*Positive, 28 April 2020*
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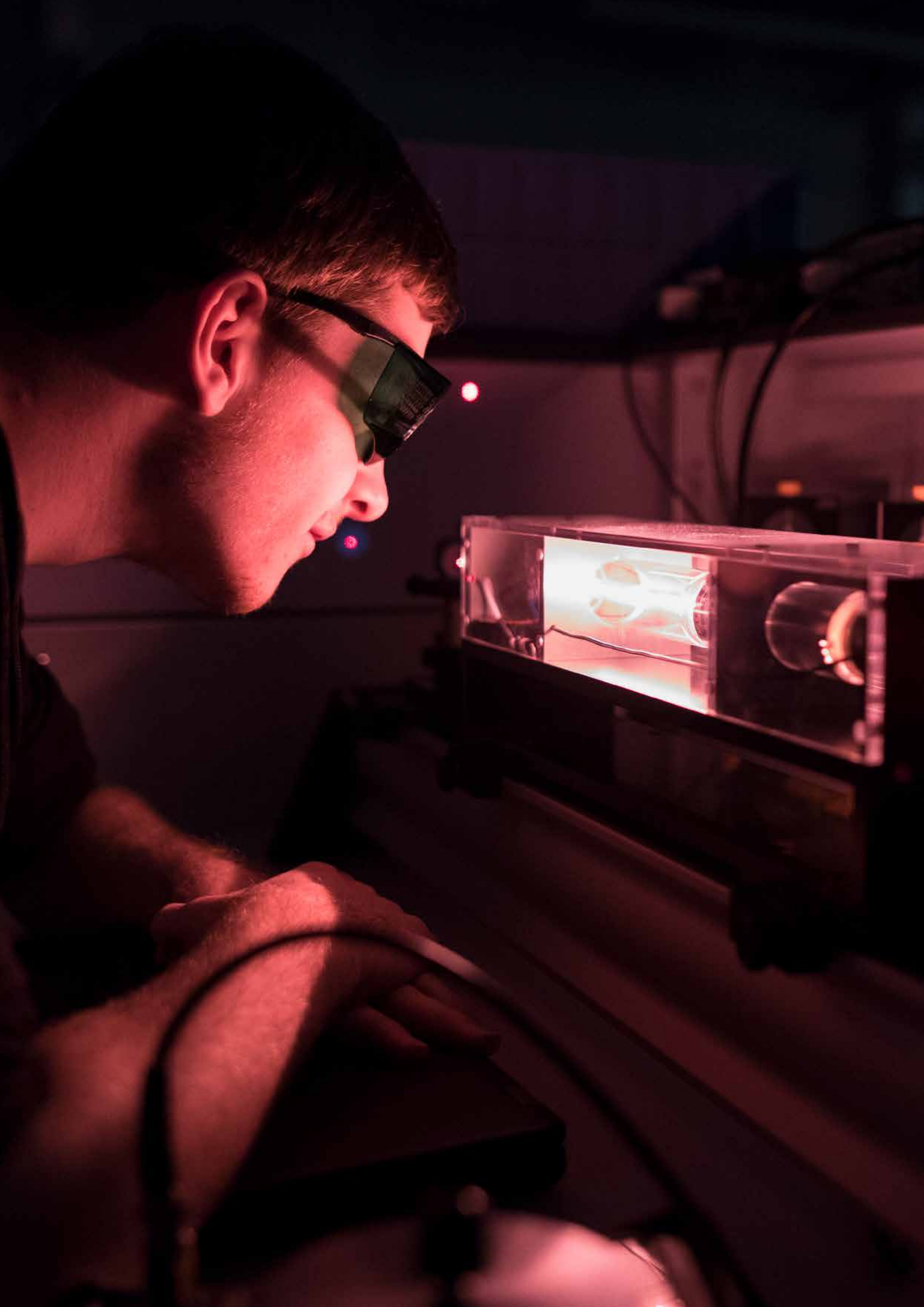

PREFACE

An understated pride and fierce dedication characterise this exceptional study programme of the University of Twente. It is regarded and respected as one of the finest of the faculty, recognised as a top programme now nine years running. Applied Physics combines strong fundamentals with real-world relevance, preparing graduates to take on complex sociotechnical challenges with a combination of conceptual, analytic and practical skills.

Our aim is continuous improvement of the programme, and we view the process of reaccreditation as an opportunity to reflect further and deeper, together. We are delighted to present this self-evaluation report of the BSc and MSc Applied Physics study programme, and look forward to sharing insights and ideas, critical and constructive, during the upcoming review.

The set up and structure of this report follows the requirements as stipulated in the NVAO framework for assessing university educational programmes. We begin with the student chapter, written with full freedom by student members of the programme committee, which sets the tone and underscores our ambitions. Thereafter, we introduce the study programme and highlight some of the unique aspects of the Twente approach. Each standard of the assessment framework is addressed in a separate chapter, including a reflection on our achievements and deficiencies. Finally, we present an outlook to future developments and aims.

Apart from the student chapter, this report was composed by Stefan Kooij, Edwin Lodder, Boukje Vreman and Cornelise Vreman, reviewed by Alexander Brinkman, Henk van den Hengel, Hans Kanger, Frieder Mugele, Herman Offerhaus, and Femke Witmans, and approved by the Faculty Board and Executive Board of the University of Twente on March 29, 2021.

On behalf of the Faculty Board,

Jennifer Herek & Nieck Benes
Dean and vice-dean for Education
Faculty of Science & Technology

STUDENT CHAPTER

In this chapter, we will focus on the four key areas that we believe play a major part in the identity of this educational programme. We will discuss the working environment and student well-being at Applied Physics, as well as the organisation and relevance of the programme. This chapter is written by the student members of the Applied Physics programme committee. This committee consists of two bachelor students and three master students, who also did the bachelor's programme. We also consulted our fellow bachelor and master students for feedback in the writing process. Of course, the coronavirus outbreak has had a large impact on the organisation of the programme. We hope that the strict regulations due to COVID-19 are only temporary. Therefore, we will focus on the situation before the coronavirus outbreak.

PLEASANT WORKING ENVIRONMENT

The ambience at the Applied Physics programme is very pleasant. The first reason is the small student population of the bachelor's and master's, which makes the interaction between students and lecturers, research groups and/or staff easier. Moreover, the staff introduces itself at the programme-specific introduction period at the start of every year and every module. This makes the staff very accessible, since asking questions, mailing or passing by offices is easier if the faces are known.

The Applied Physics study association plays a big part in the ambience as well. Every year Arago hands out a prize to the most popular lecturer and staff occasionally attends Friday afternoon drinks. Since almost every student is a member of the study association Arago, and the staff is close to Arago, this makes the threshold for giving feedback lower.

The Quality Assurance Committee is charged with the executive duties of evaluating the modules by means of panel meetings and surveys. This committee (OKC) organises two evaluation meetings for every module. At the first meeting, they discuss the module with the students without the presence of lecturers, and at the second one, the lecturers are also involved. The feedback from these panels is taken into account the year after. In the master's, only twice a year a panel is organised due to the variety of subjects. Generally, subjects are evaluated among students by means of surveys every three years. New or newly changed subjects are evaluated immediately. The Quality Assurance Committee and the student members of the programme committee try to make themselves visible to students, to ensure a low threshold for giving feedback. All in all, the subjects are well evaluated and the staff is always looking for improvement.

ORGANISATION AND CURRICULUM

The Bachelor's in Applied Physics is overall well organised. The courses, practicals and projects in each module are well connected. Furthermore, successive modules and courses have a logical order, and the organisation of the whole and the individual parts of each module is clear. The planning of all the practicals, lectures and exams is sometimes challenging since a module is only ten to eleven weeks long. Despite this, the bachelor's is flexible and can be adapted to the individual needs of students. This also makes extracurricular activities very accessible to students, which is encouraged to do in both the Bachelor's and Master's in Applied Physics. Extracurricular activities include: joining a committee, studying abroad, be part of a student team or do a board year at the study association Arago.

For the Master's in Applied Physics, the organisation is different from the Bachelor's. Students must choose their courses according to their interest in coordination with the board of examiners. In each quarter, there is also a mandatory course. Individual courses are well organised, relevant and connect well to the bachelor and other master courses. However, planning is sometimes difficult due to the mandatory courses in each module.

STUDENT WELL-BEING

The work pressure for both the bachelor's and master's is quite high. This makes sure that students learn to plan and to work efficiently. However, sometimes the students get overworked. While there is quite some help for students with mental health issues, the availability of this help (student psychologists, possible financial support, mindfulness workshops etc.) can be presented better. The staff is already off to a good start. For every student, there is a mentor available to help with these kinds of problems. Last year, every small group of first-year students also had a lecturer as a tutor. With this tutor, the students get to talk about their interests in physics, which could be something completely different than their current subjects. Furthermore, the staff and UT itself are already trying to promote well-being workshops or student psychologists. This is very important and can be further improved.

Since the work pressure is high, most students have some delay to be able to do extracurricular activities. As said before, the bachelor's programme is flexible, so this delay is not a real problem: missing one subject does not mean that you will be delayed by one year. The master's is less flexible, but we understand that this is difficult to improve.

RELEVANCE RESEARCH/BUSINESS COMMUNITY

Both the bachelor's and the master's are very well connected to the research that is being done at the university. The professors of the research groups are generally very accessible to the students and as mentioned before: there is a very open-door attitude. Obtaining a master or bachelor thesis assignment can be as easy as walking into the professors' office or by writing a quick email. Students are usually very welcomed into a research group and are made to feel part of it. Most of the physics research that is being done at the Faculty of Science & Technology is well represented in the curriculum of the master's and bachelor's. Although not all research areas are covered in the mandatory curriculum, students have the possibility to learn about the smaller research areas through specialisation courses.

Most of the students, however, will obtain a job in business after their master's. This is no surprise, since Applied Physicists are also much desired outside universities. 45% of the master students continue to obtain a PhD, while the other 55% find a job in education, business and so on. We believe that the opportunities for an Applied Physics graduate in the business world are already highlighted well in the bachelor's programme by visiting nearby companies. In the master's programme this is done through an internship of 20 to 30 EC, which can also be done at a research institute. But we believe that the students could be better informed about the different possibilities for an Applied Physics student in the business world. This will also help the students to make a more informed decision about the internship. It is for example also possible to do the master assignment at a company, but this fact is not highlighted very often.

CONCLUSION

Overall, we are very happy with both the bachelor's and master's programme. The small scale creates a pleasant working environment, which allows each student and teacher to be listened to. Despite the tight planning of both programmes, there are many opportunities for extracurricular activities. However, for some students, the workload of the study and extra activities can be overwhelming. We are confident that the programme board and staff will continue to improve the programme in the future.

The student members of the Programme Committee:
Annelies Dekker, Pim Dekker, Léon Goedegebuur, Sofie Kölling, Emiel Slootman, Macy Vreman, Marel Vrerink

Enschede,
January 2021

INTRODUCTION

MISSION AND MOTTO

Society rapidly changes in response to global developments, resulting in increasingly more complex societal challenges. The role of academics in general, and Applied Physicists specifically, changes accordingly. These developments demand for professionals who can come up with creative solutions for interdisciplinary problems, building on disciplinary knowledge, skills and attitude.

Our mission is to enable students to develop themselves optimally by exploring the limits of their individual abilities and ambitions and venturing beyond them, in the role that society expects from them. The student profile that we strive for is characterised by the following aspects: independent, creative, problem-solving, authentic, reflective and critical. They are team players with a keen eye on their own role, but also the role and perspective of others. Ultimately, Applied Physics graduates should be aware of their responsibilities as academic professionals on the job market and in society.

Education within the Applied Physics programme is aimed at maximally contributing to qualification, socialisation and personification, the pillars of modern academic education. We consider it essential that teaching serves the individual learning needs of each student[1].In addition to a well-defined part of the curriculum, there is ample room for individual choices, both in width and depth. Sufficient flexibility enables us to design customised, personal study programmes, not only to optimise study duration, but also to allow for extra-curricular activities, such as serving on a board or committee, participating in student teams, organisation of events, study tours, etc. In that respect, we expect students to take responsibility for their own learning process. The learning process is primarily driven by the student's intrinsic motivation to develop within and outside the discipline. The role of staff and teachers is to facilitate as much as possible, as partners in the learning process. In that respect, we envisage students as our future colleagues.

A strong sense of community among students, teachers and staff is essential. Our motto **'Together we educate: partners in teaching and learning!'** [2] is reflected in our common commitment to being involved in all aspects of the programme. In various ways we facilitate community building, and also closely collaborate with Arago, the study association for Applied Physics. Together we organise numerous activities to promote interaction among students, young and old. Education related activities include study evenings, celebrations, company presentations, and excursions. In favour of socialisation, we organise many events, bringing together staff, students and teachers. This has led to a unique atmosphere, characterised by mutual trust, which provides a solid foundation for personal development in a familiar, stimulating and above all safe environment. And let's not forget, studying should be fun!

STUDENT APPRECIATON

In the following chapters, we will show that, in line with our motto, we strongly value the input, contribution and opinion of our students and alumni. For many years now, the annual National Student Survey (in Dutch 'Nationale Studenten Enquête', NSE) provides valuable feedback from students who participate in the education we offer. Similarly, the National Alumni Survey is a source for feedback, but the response rate of that one is generally lower.

Besides survey results, the strong sense of community allows for frequent contact between students, teachers and staff. The resulting open atmosphere enables transparent, honest and respectful communication. In this way, we join forces to provide the best possible education, and therewith creating a unique learning experience for each student. The reader is referred to the student chapter (at the beginning of this report) to learn about their perspective. As we describe in our reflection on this student perspective, it perfectly coincides with all aspects of the programme that we devote our efforts to. In turn, it is highly rewarding to see our efforts reflected in appreciation by students, as expressed

[1] 'De succesformule van technische natuurkunde', U-Today (2018); utoday.nl/spotlight/66208/de-succesformule-van-technische-natuurkunde

[2] Our motto in Dutch: **'Onderwijs voor, door en met studenten'**

in the NSE. The scores on general criteria, i.e. study programme in general, atmosphere and whether students would recommend Applied Physics at the University of Twente to others, are summarised in table 0.1. The exceptionally high scores lead to high rankings in the Keuzegids Universiteiten and Keuzegids Masters. The Bachelor's in Applied Physics has been a top-rated programme for nine years in a row[3], with a second place of all bachelor's programmes (nationwide) in 2019.

Table 0.1 *Student appreciation (on a scale of 1-5) on three most general criteria, derived from the NSE.*

Student appreciation (on a scale 1-5)	Bachelor					Master				
	2019	2018	2017	2016	2015	2019	2018	2017	2016	2015
Your study programme in general	4.61	4.63	4.59	4.39	4.36	4.54	4.30	4.49	4.39	4.36
General atmosphere within programme	4.77	4.77	4.71	4.54	4.61	4.54	4.53	4.43	4.43	4.49
Recommend friends, family, colleagues	4.46	4.58	4.63	4.45	4.37	4.49	4.35	4.64	4.58	4.65

OUTLINE

As the University of Twente was positively evaluated after the institutional audit in 2019, the Bachelor's and Master's in Applied Physics will be assessed in the scope of the limited framework as defined by the Dutch Flemish Accreditation Organisation (in Dutch 'Nederlands-Vlaamse Accreditatieorganisatie', NVAO). This self-evaluation report follows the four standards as defined by the NVAO.

In the following section, we position the programme within the university, the faculty and describe the organisational setting. In chapter 1 the intended learning outcomes are presented and justified. The organisation of our education is described in chapter 2, in which we elaborate on the teaching and learning environment. Chapter 3 is devoted to student assessment, and in chapter 4 we reflect on what we achieve within our programmes in relation to the learning outcomes. We finish this report by reflecting in terms of strengths and opportunities, and by focussing on the future, and some of the challenges that lie ahead.

Supporting information and data are available in appendices, and we have set up a supplemental material website[4] with more details, examples and background information.

[3] Only 8 of the nearly 400 bachelor's programmes in the Netherlands have managed to obtain the title 'top-rated programme' for 9 consecutive years.

[4] utwente.nl/nl/tn/self-evaluation-2021

ORGANISATIONAL SETTING

The Bachelor's and Master's programmes in Applied Physics (AP) are embedded in the Faculty of Science and Technology (TNW), one of the five faculties of the University of Twente. The organisation of the faculty with respect to applied physics education is schematically shown in figure 0.1, indicating the relation between the various bodies.
The faculty management lies with the faculty board, consisting of the dean (prof.dr. Jennifer Herek), the vice-dean for education (prof.dr.ir. Nieck Benes), the vice-dean for research (prof.dr.ir. Wiendelt Steenbergen), managing director (Jan-Willem Timmerman), and a student assessor (Kevin Klein Gunnewiek), who has an advisory role. The Faculty Board meets on a weekly basis.

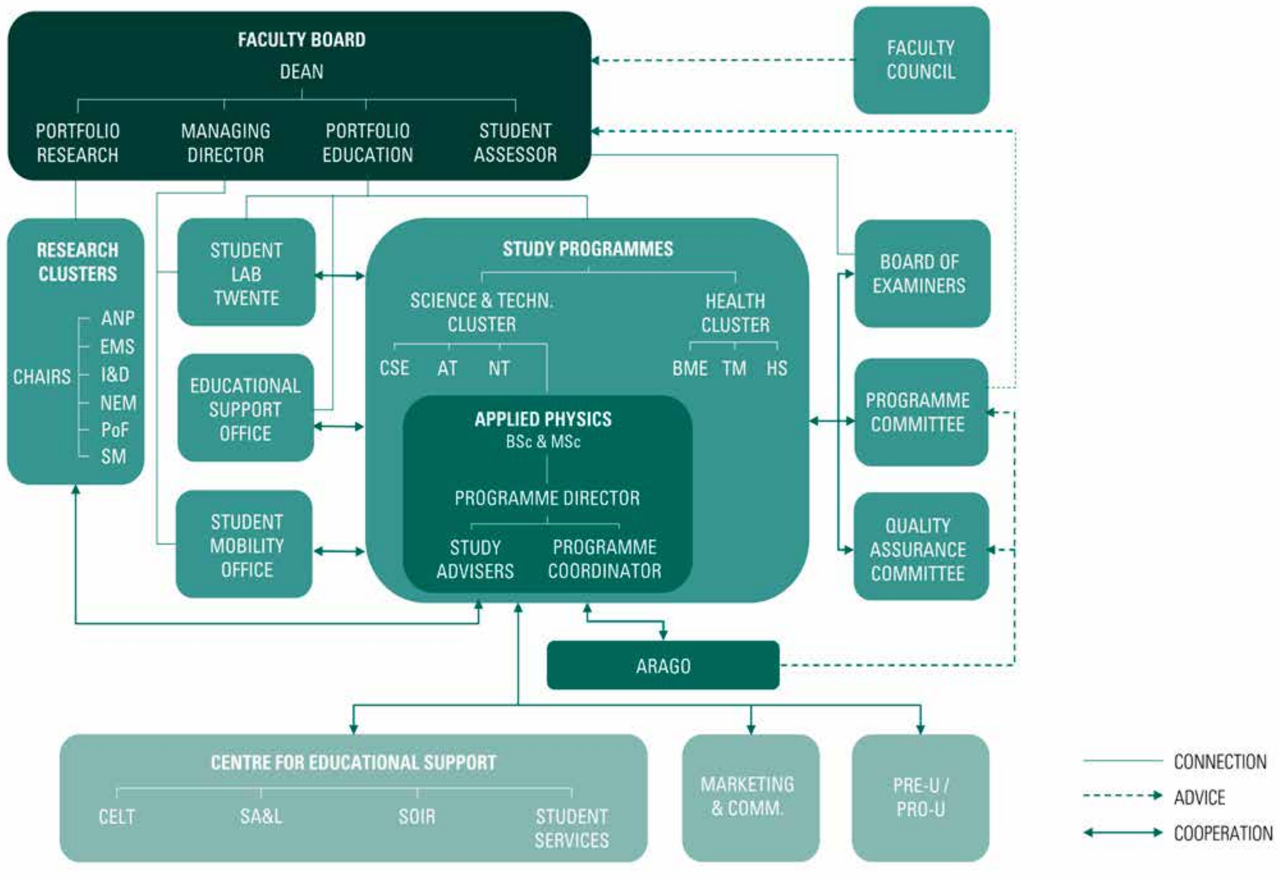

Figure 0.1 *Organisational structure of Applied Physics in the Faculty of Science and Technology*

ORGANISATION OF EDUCATION

The director of education (dr. Stefan Kooij), appointed by the faculty board, is responsible for the content and quality of the programme. Support within the programme is provided by a programme coordinator (Edwin Lodder), and two study advisers (dr. Dejana Djokovic-van Damme and dr.ir. Carlijn van Emmerik).
Further support within the faculty is provided by:

- *Student Laboratories Twente* (SLT; headed by dr. Jeroen Verschuur and dr. Stefan Kooij, under the responsibility of the vice-dean for education and the managing director) facilitates experimental work for students in a laboratory environment.
- *Educational Support Office* (ESO; headed by policy officer Eline Marsman, under the responsibility of the vice-dean for education) is responsible for general educational policy, quality control and e-learning.
- *Student Mobility Office* (SMO; headed by coordinator international affairs Rita de Wilde-Brink, under the

responsibility of the managing director) coordinates internships, exchange and international collaborations in education.

- On a central level, the *Centre for Educational Support* (CES) provides direct support via *Student Affairs & Logistics* (SA&L) and the *Centre for Learning and Teaching* (CELT). Other central support for education is available from Marketing and Communication, as well as the *Pre-University programme* (Pre-U).

ORGANISATION OF RESEARCH

The faculty's research programmes cover a broad scope, ranging from physics, chemistry, and nanotechnology to biomedical and health technologies. The research is organised in eleven clusters, assembling various complementary chairs on a scientific topic, and representing disciplinary strengths and scientific excellence. The clusters bring focus on content, quality, and success in both teaching and research.

The following clusters are involved in and are delivering modules/courses to the Applied Physics programmes:

- Applied Nanophotonics (ANP)
- Energy, Materials & Systems (EMS)
- Imaging & Diagnostics (I&D)
- Nano-Electronic Materials (NEM)
- Physics of Fluids (PoF)
- Soft Matter (SM)

The chairs and other full professors of the clusters and research groups involved in the Applied Physics programmes together with the programme director constitute the *Chamber of Professors of Applied Physics* (Kamer Technische Natuurkunde). This council meets once every month to also discuss educational matters.

ADVISORY BOARDS & COMMITTEES

The most important advisory boards and committees related to the Applied Physics programmes:

- The *Faculty Council* of the Faculty of Science & Technology, consisting of seven elected staff members and seven elected students, advises the faculty board with respect to research, education and finance, as established by law.
- The *Board of Examiners* for Applied Physics, consisting of a chairperson, a secretary, three other staff members and one external member, is responsible for assurance of assessment quality in accordance with the law and with assessment policy and regulations.
- The *Programme Committee* for Applied Physics is the primary advisory body for education, as established by law. The programme committee consists of five staff members and five students. The staff members are experienced lecturers, representing the different clusters involved with Applied Physics, while the students equally represent all student cohorts.
- The *Quality Assurance Committee (Onderwijskwaliteitcommissie, OKC-TN)*, chaired by the quality assurance coordinator (embedded in ESO) and consisting of bachelor and master students, is responsible for evaluating all study units of the bachelor and master programmes, in consultation with and on behalf of the director of education.
- *Study Association Arago*, the study association for Applied Physics at the University of Twente[5] is a strong partner in the education process.

[5] arago.utwente.nl

1. INTENDED LEARNING OUTCOMES OF THE PROGRAMME (STANDARD 1)

The mission and motto of the bachelor's and master's programmes were presented in the Introduction. In this chapter, the intended learning outcomes (ILOs) are described to demonstrate standard 1 of the NVAO accreditation standards. We summarise the domain-specific framework of reference (DSFR), as recently formulated for the Dutch Applied Physics programmes, followed by the description and justification of the ILOs of the bachelor's and master's programmes. The distinctive features are listed and we include some remarks on language and internationalisation, to end with a reflection.

1.1 DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

The Applied Physics programmes at the universities of Delft, Eindhoven and Twente have jointly formulated the domain-specific framework of reference (DSFR). Based on the Tuning 2018 document[6], a set of criteria has been drawn up, which provides the main benchmark for design of the ILOs of the academic programmes in Applied Physics in terms of competence descriptors, which are a combination of knowledge, skills and attitude. In appendix 1.1, the criteria are placed into categories related to the Qualification Framework for the European Higher Education Area (QF EHEA[7]) descriptors and also to the Meijers' criteria[8]; a graphical representation is depicted in figure 1.1.

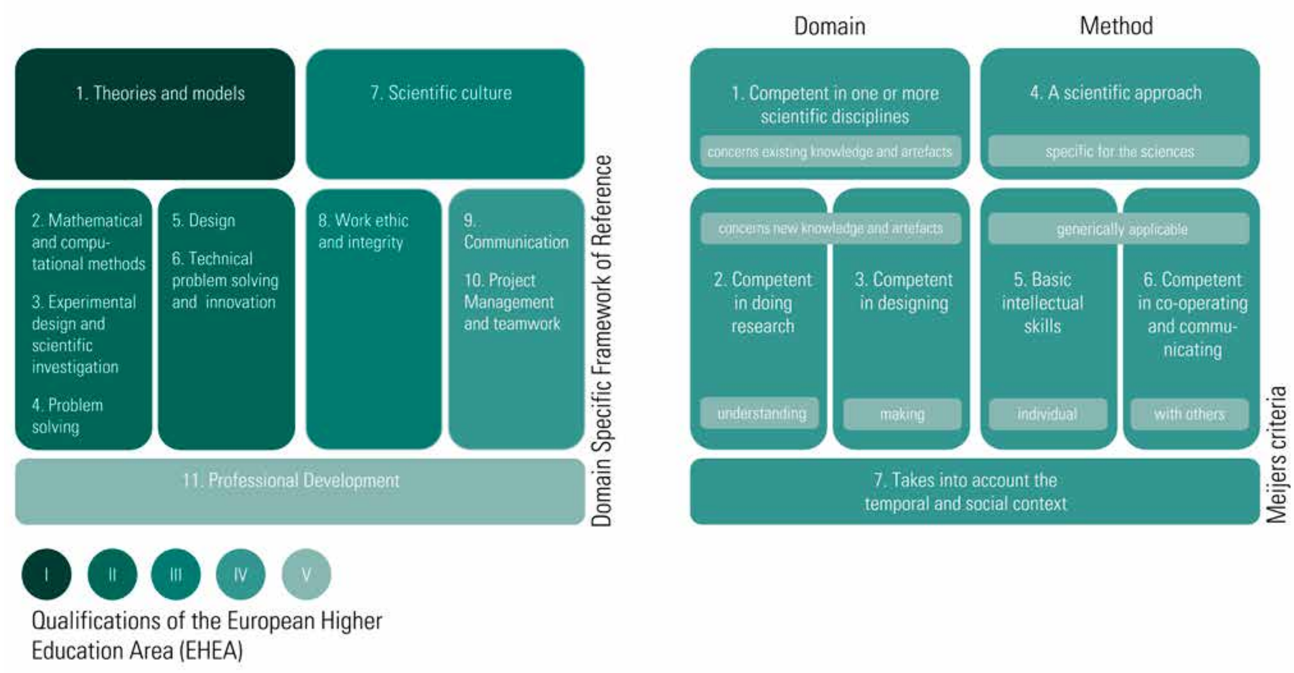

Figure 1.1 *Graphical representation of the relation between the criteria in the DSFR and the Meijers' criteria, while also categorising the criteria in terms of the EHEA descriptors. See also appendix 1.1.*

The Meijers' criteria were specifically developed by the three technical universities in The Netherlands for academic bachelor and master curricula.

[6] calohee.eu/wp-content/uploads/2018/12/WP-4-Del.-1.5-Guidelines-and-Reference-Points-for-the-Design-and-Delivery-of-Degree-Programmes-in-Physics-FINAL-17DEC2018.pdf
[7] ecahe.eu/w/index.php?title=Framework_for_Qualifications_of_the_European_Higher_Education_Area
[8] utwente.nl/en/ces/celt/toolboxes/educational-design/1a_course_embedded_in_curriculum/criteria-for-academic-bachelors-and-masters-curricula.pdf

The difference between the bachelor and master criteria is reflected in the level of knowledge and skills, the degree of handling complexity, information processing and the ability to autonomously operate in a professional environment. The bachelor graduate has developed competences building on their secondary education, providing a solid basis to continue onwards in a technical programme at master's level or potentially entering the labour market at a comparable level. The master graduate has competences founded upon and exceeding those of the bachelor level, providing a basis for originality in developing and applying new ideas. The level of autonomy pursued in the master's is higher, and the area of expertise is more specific.

1.2 INTENDED LEARNING OUTCOMES

The intended learning outcomes (ILOs) for the bachelor's and master's programmes in Applied Physics are based on the profile as described in the Introduction and in the DSFR in appendix 1.1. They reflect our aim to educate independent, critically thinking academic professionals, who are equipped with competences to contribute to the field of engineering physics and to society as a whole.

The ILOs have recently been reformulated, and, as such, deviate from what is presently stated in the Education and Examination Regulations (EER) available on our website. As of September 2021, they will be updated in the EER. A brief comparison between the former and reformulated ILOs is provided in appendix 1.2.
In table 1.1 an overview is given of the ILOs of the bachelor's and master's, where we distinguish five categories of competences relating to (i) knowledge, (ii) skills, (iii) personal development, (iv) communication and (v) organisation. In some cases, the ILOs of the master's programme are formulated as an advanced version of the learning outcomes of the bachelor's, while others are identical, but apply to more complex theory, problems and context in the master's. The last column in table 1.1 relates the ILOs to the different categories of criteria set by the DSRF.

To set a benchmark for the ILOs we also take into account the opinion of the professional field, and therewith also that of our alumni, on the graduates we delivered in the past and will deliver in the future. We often have the chance to interact with alumni and/or colleagues, for instance during company presentations (organised by study association Arago), excursions to industry, study tours, reunions or other visits of alumni to the campus, when they, for example, contribute to our courses. Based on feedback gathered on these occasions, but also from the alumni surveys (we recently conducted one, the results of which will be presented with standard 4), we conclude that the intended learning outcomes are up to date and consistent with the (future) demands of the professional field. More details on the connection to our alumni and the professional field can be found in sections 4.2 and 4.3, and also appendix 4.2.

1.3 DISTINCTIVE FEATURES

Applied physicists distinguish themselves from physicists from non-technical universities by their awareness of and sensitivity to applications, and by their technical skills to realise those applications. What sets Applied Physics apart from other technical disciplines is the higher level of fundamental knowledge.

Several characteristics distinguish Applied Physics at the University of Twente from other (applied) physics programmes, both nationally and globally. In general, partly owing to the small scale of the Applied Physics programme at the University of Twente, students and staff form a tight community with a lot of interaction and active participation.

As programme staff, teachers and management, we consider ourselves partners in the learning process. This is one of the core values in our education and paves the way for unique student participation throughout the programme. This, in turn, leads to exceptionally high student appreciation, as mentioned in the Introduction. In the following paragraph, we summarise the distinctive features of the bachelor's and master's programmes.

Table 1.1 Intended learning outcomes of the Bachelor's and Master's programmes in Applied Physics at the University of Twente, and their relation to the criteria listed in the DSFR (appendix 1.1).

Bachelor	Master	DSFR
Knowledge – The Applied Physics graduate:		
has comprehensive technical and scientific knowledge of the relevant fields in (applied) physics in combination with relevant mathematics and computer science	has thorough technical and scientific knowledge of essential theories in the domain of (applied) physics and mathematics, and can relate to other disciplines in a multidisciplinary environment	1
has an overview of the various specialisations in the domain of (applied) physics, and their relevance in industry and academia	has advanced knowledge and understanding and the ability to apply this knowledge to design and research within one or more sub-areas of the (applied) physics domain	1
Skills – The Applied Physics graduate:		
can apply basic mathematical, experimental and computational tools and methods to solve problems in physics	can apply advanced mathematical, experimental and computational tools and methods to solve complex physical problems in a broad context	2
is familiar with scientific research methods within the physics domain and can identify basic physics problems in a limited context	can apply the scientific research method and identify advanced physics problems in their full context	3
can contribute to the solution of research or design problems in the field of engineering physics using a systematic approach	can identify, formulate and solve research or design problems in the field of (engineering) physics using a systematic approach.	4
is aware of the scientific design method and can use physics to contribute to innovative solutions and verify their validity	can apply the scientific design method, divide a design problem into different sub-problems, and can apply physics expertise to realise complex innovative solutions	5,6
Personal development – The Applied Physics graduate:		
is critical, self-thinking, and able to reflect on their own performance and personal responsibilities		7
is aware of the role of applied physics in science and society, and of the international orientation of the discipline		7
is aware of the possibilities on the labour market or to continue studying with an academic master's after completing the bachelor's programme	has experience with the possibilities on the labour market and in academia after completing the master's programme	7
can decide based on integrity and take responsibility for their own performance	can decide based on integrity and ethical norms in research and industrial environments and take responsibility in a local, national and international setting	8
can select, process and evaluate information from different sources		9
Communication – The Applied Physics graduate:		
can effectively communicate on technical-scientific topics orally and in writing in a professional manner	can effectively communicate with a variety of audiences to inform, influence and discuss using various techniques and language appropriate for the audience	9
Organisation – The Applied Physics graduate:		
can organise and complete a simple project individually or as part of a team by collaborating, taking initiative and being sensitive to inclusivity issues	can organise, contribute to and complete a complex project, either individually or as part of a team by collaborating, taking the lead and being sensitive to inclusivity issues	10
has the attitude to learn and is able to maintain, improve and integrate new knowledge and academic skills into existing competences		11
can identify relevant competences for further development after completing the academic programme, and can link strengths and weaknesses to personal and professional development goals (life long learning)		11

1.3.1 BACHELOR'S PROGRAMME

- A strong, student-focussed approach with a top sports mentality, motivating our students to push their limits: together with each student we explore what he or she needs to get the most out of their studies for their own personal development.
- The introduction of the Twente Education Model (TOM) in 2013 initiated a redesign of the curriculum. Thematic modules enable coherent education of different subjects, all combined into an overarching project.

- A general academic skills line runs throughout all modules, connecting the various courses and projects, to be summarised and concluded with the bachelor assignment. Skills include programming, research, design, organisation, job orientation, and more general project-related skills.
- The programme has a clear structure, with the first year focused on basic knowledge and skills, building on what is learned in high school. The second year deepens knowledge, further develops skills, including those needed for complex problem solving. The third year is geared towards broadening the perspective, possibly also in an international context, with a lot of choice in minors, electives and the final assignment.

1.3.2 MASTER'S PROGRAMME

- A highly flexible approach, with considerable freedom of choice, for example in the direction of specialisation, electives, internship and final assignment. We aim to provide the most optimal learning experience for every individual student, in line with their specific competences, interests and ambitions.
- Core courses, compulsory for all students, cover the broad range of Applied Physics competences, including fundamental physics, mathematical and computational physics, engineering physics, experimental physics, and cultural and ethical awareness. Details are provided in the next chapter.
- A strong link to key areas of physics-related research in Twente, including materials science, nanophotonics, fluid dynamics and bio(medical)physics.

1.4 LANGUAGE AND INTERNATIONALISATION

In the bachelor's, the primary language of instruction is Dutch. Nationwide, but also within the University of Twente, there has been considerable discussion on language and internationalisation. The language policy of the University of Twente, established in 2018, posed the ambition to offer all bachelor's programmes in English by 2020. The primary reason was to enable admission of all nationalities, therewith contributing to the university's internationalisation strategy.

The decision on the language adopted by a programme ultimately lies with the programme management. In 2013, the programme committees of Chemical Technology and Applied Physics jointly advised to only consider switching to English after a careful evaluation of the pros and cons. This advice was reconfirmed in 2016, also following discussions with both the programme committee and our students.

To guarantee the overall quality, and in line with consistent feedback from our alumni, we keep offering the bachelor's in Dutch. Physics in general proves to be conceptually challenging and enabling students to communicate in their mother tongue proves to be highly beneficial for their understanding and performance. Moreover, for a considerable fraction of our students, language is not their most developed competence and therewith an additional challenge. To ensure sufficient depth, both teachers and students have expressed their preference to discuss in their native language.

Despite Dutch being the primary language, quite some education is offered in English. In fact, we deliberately choose to expand the use of English during the programme, to facilitate preparation for entering a master's and/or the international job market. Most course material is in English, and courses taught together with other programmes (for example in mathematics), or those taught by non-Dutch speaking staff, are in English. Also, the bachelor assignment is often performed in a research group or company where English is the primary language of communication. As such, students develop sufficient language skills. For those who need extra training, the UT Language Centre offers extracurricular workshops and courses.

Considering the international orientation and close connection to research, the language of instruction in the master's programme is English. Unlike the bachelor's, which comprises basic applied physics knowledge and skills that are

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[9] 'A European specification for physics bachelor studies', prof.dr. H. Ferdinance, Eur.Phys.Soc. (2009); cdn.ymaws.com/www.eps.org/ resource/resmgr/policy/eps_specification_bphys.pdf

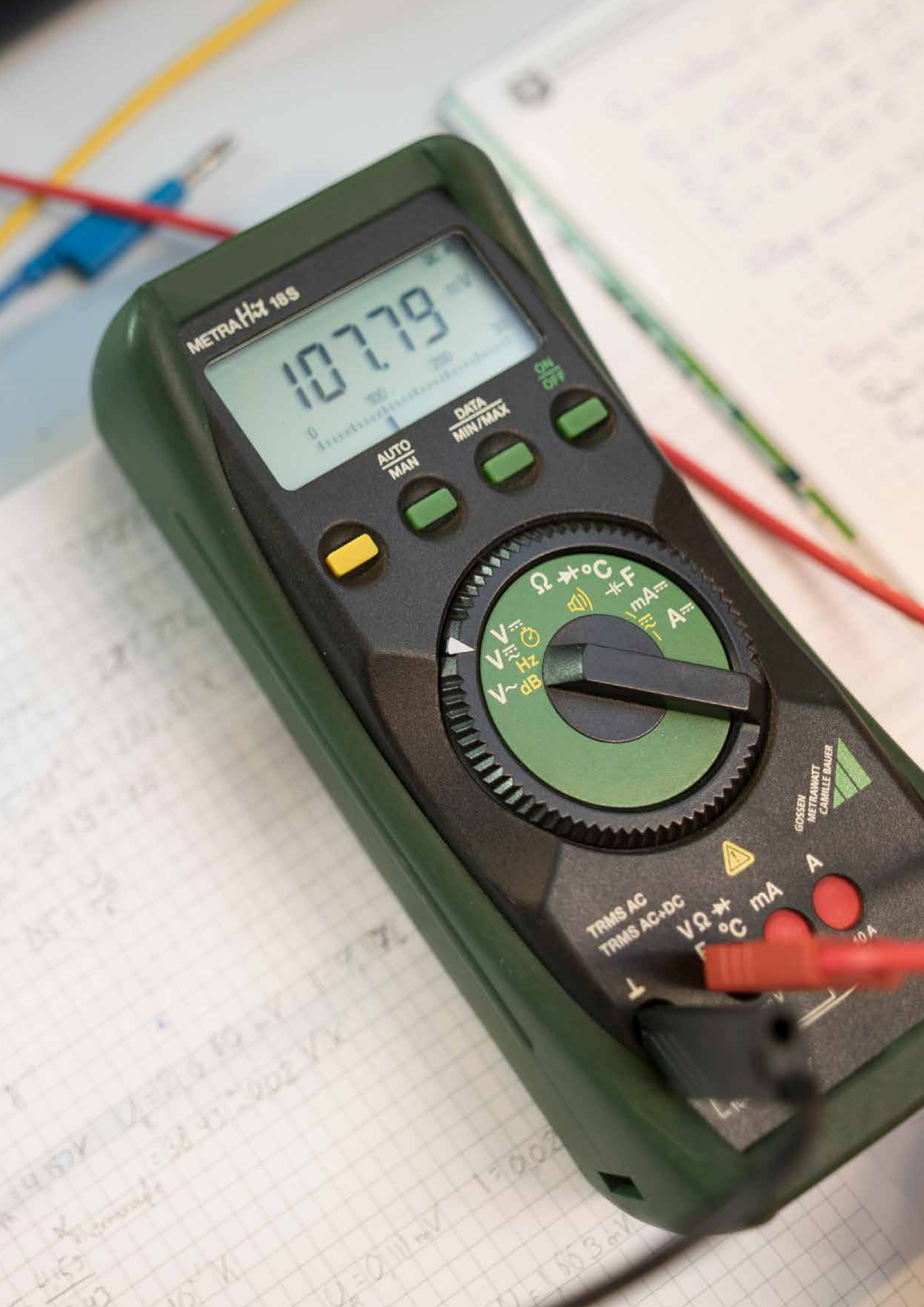
essentially the same across Europe[9] and the globe, the unique aspects of the master's make it considerably more relevant on an international scale. Students in the master's, but also in the bachelor's, as well as alumni, conclude that the Applied Physics programme offers sufficient preparation for an international career, even though it is not very explicitly part of the curriculum. Students are well aware that we encourage them to seriously consider doing part of their studies abroad, for example, by doing a minor, internship, or even the final assignment elsewhere. Moreover, the frequent contact with staff and/or teaching assistants of many different nationalities is highly appreciated. Finally, the many optional (extra-)curricular activities, such as study tours, but also participation in student teams with global competitions, contribute to their development in an international context.

1.5 REFLECTION

Based on what is described above, the Bachelor's and Master's programmes in Applied Physics have an academic level and a scientific orientation. The research programmes of the Faculty of Science and Technology, and more specifically within the Applied Physics domain, clearly contribute to both programmes in terms of subjects and staff. This ensures a close link between education and research. The 4TU Meijers' criteria were recognised by the NVAO in 2006. As outlined in the DSFR (appendix 1.1), the ILOs relate to and cover all the Meijers' criteria, therewith guaranteeing the focus on engineering as well as academic level and scientific orientation.

The actual level of our students is good, given that they contribute to scientific research in our research groups during their bachelor and master assignments, and manage to build up successful careers after their studies, both within and outside academia. This is further demonstrated in chapters 3 and 4.

As reflected in the ILOs, during the bachelor phase students are trained at a junior level in handling and solving problems with a sufficient degree of autonomy. In a broader sense, bachelor graduates are in a position to make their scientific knowledge relevant in a position for which a bachelor's degree is required and where Applied Physics knowledge and skills are useful and necessary in research, design or in projects. This pertains to a career in industry or when continuing with a master's programme. In comparison with the competence development in the bachelor's programme, the emphasis in the master's is on a higher degree of complexity and responsibility. For a master graduate in Applied Physics, it is not sufficient to know or to be able to do something, but he or she is expected to have developed a critical, independent, reflective attitude toward applying and possibly further developing their knowledge and skills, with the ultimate goal to provide a contribution to science, industry and society.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2. TEACHING-LEARNING ENVIRONMENT (STANDARD 2)

In this chapter we describe the teaching-learning environment, as defined in standard 2 of the NVAO accreditation. We first focus on the setup and contents of the bachelor's and master's programmes, the learning and teaching methods, and we describe the relation between the intended learning outcomes (ILOs) and the programme contents. We outline the scientific orientation, the relation to the professional field, and present the academic staff. Subsequently, we comment on the admission procedures, student intake, feasibility, study load, and extra-curricular opportunities. Facilities are described, including student counselling, information supply and programme specific facilities, to conclude with an overview of our quality assurance system. We end the chapter with a short reflection and an overview of relevant results of the National Student Survey to demonstrate student appreciation. More detailed information on our bachelor's and master's programme and the integration and cohesion of our curricula can be found in appendices 2.1 and 2.2.

2.1 SETUP AND CONTENTS OF THE BACHELOR'S AND MASTER'S PROGRAMMES

The Bachelor's programme in Applied Physics offers students a broad and solid base of modern physics, mathematics and computer skills, combined with essential academic skills and their application in the different domains of physics. The Master's programme in Applied Physics builds on the foundation developed in the bachelor's and provides an immersion into the specialisations within the Applied Physics domain. In the master's we aim to achieve the ideal balance between fundamental physics, mathematics, engineering and experimental skills. The themes that are covered within the master's programme are in alignment with our primary research clusters:

- Applied Nanophotonics (ANP)
- Energy, Materials & Systems (EMS)
- Nano-Electronic Materials (NEM)
- Physics of Fluids (PoF)
- Soft Matter (SM)

For all programmes at the University of Twente, the academic year is divided in four quarters of 10 weeks each. The study load for each quarter is 15 EC (= 420 hours). Two quarters form a semester.
Here we only describe the standard curricula. Options for students who seek more challenge, e.g. excellence programmes, are mentioned in section 2.9.

2.1.1 SETUP OF THE BACHELOR'S PROGRAMME: THE TWENTE EDUCATION MODEL

In 2013, the University of Twente introduced the Twente Education Model (TOM)[10] for its bachelor's programmes. The educational vision of the University of Twente is to:

> *"invest in a sustainable future by educating students who can grow and develop as society changes, who are able to create new knowledge based on their own specialisms in engineering, science or management, and who are aware of the impact this has on society. This foundation will enable Twente graduates to make an impact by designing sustainable solutions and working on ground-breaking research."*
> *Source: TOM information site (utwente.nl/en/tom)*

TOM is based on (i) thematic modular education, (ii) a focus on three professional roles: researcher, designer and organiser, and (iii) student-driven learning (SDL), and is characterised by coherent learning activities.

[10] In Dutch 'Twents Onderwijs Model '

The bachelor's programme consists of thematic modules, each with a nominal study load of 15 EC. Each module consists of different courses, which are taught in a coherent way. The module brings together theory and practice, research, design, self-study and teamwork. Central to most modules is a group project, in which students not just apply, but also independently gain new knowledge and skills. In the project, teams are confronted with an open-ended problem that is too large and diverse to solve individually. Students must engage in teamwork, organise their activities and become aware of the different roles within the project team.

Within TOM the number of contact hours is relatively high and teaching methods are varied and student centred. Furthermore, there is a focus on student-driven learning (SDL).

> *"Student-Driven Learning, as intended for use by the University of Twente, can be described as the curricular foundation which supports and encourages students to develop self-determination and the "willpower" to steer their own academic progress. It allows students to take control and regulate their learning, and to adapt their behaviour to correspond with their chosen goals and values."*
> *Source: brochure "Student Driven Learning at the University of Twente"*

Student-driven learning implies that we stimulate students to take control over their own learning process and to make personal choices in, for example, planning and educational activities. SDL is best demonstrated in the group projects, where students have the opportunity to choose their own unique path to the solution of a problem. But also in the entire programme, we encourage students to take on an active attitude toward their work and study, and to reflect upon their performance. In their learning process, students are extensively guided, supervised and stimulated by the lecturers, tutors, coaches and experts, but always within their own responsibility. We strongly value intrinsic motivation as a driver for self-directed learning, during the study but also thereafter.

2.1.2 CONTENTS OF THE BACHELOR'S PROGRAMME

The nominal duration of the Bachelor's programme in Applied Physics is three years and comprises a study load of 180 EC. The programme is divided into 12 thematic modules of 15 EC each. In table 2.1 a summary of the bachelor curriculum is given, indicating the themes of the various modules. A more detailed description is provided in appendix 2.1, including an overview of contact hours, learning lines and cohesion within the programme.

The bachelor's programme is designed in line with the ILOs (table 1.1) to introduce students to the broad scope of applied physics. The module themes and courses reflect the subjects considered relevant in any physics bachelor's programme[9], including mechanics and thermodynamics, optics and electromagnetism, quantum physics, mathematics and computing, and experimental and laboratory work. Specific to applied physics, the curriculum also includes signal analysis and modelling of systems, and also focusses on fluid dynamics.

Besides gaining technical skills and disciplinary knowledge, students also develop more general academic and reflective skills and so-called soft skills, e.g., writing a technical report, presenting a paper, working in teams, critical thinking, scientific integrity, etc. More information about individual modules and courses is available in the Osiris course catalogue and also in the supplemental material.

YEAR 1

The first year is designed to allow further development of what was learned in high school and to explore the broad field of Applied Physics from different perspectives. In each module, students focus on a particular aspect of applied physics, and the team projects have a direct link to the main themes in the various modules.

YEAR 2

In the second year, everything revolves around deepening the knowledge gained in the first year, as well as the application thereof (e.g. Module 5). Students are introduced to three important research areas, i.e. optics, materials physics and physics of fluids.

YEAR 3

The third year of the bachelor's allows for broadening depending on the interests of the student. For modules 9 and 10, students choose a minor programme of 30 EC. Module 11 concentrates on preparing for the bachelor assignment and on making an informed choice for a next career step, either a subsequent master's or a job outside academia. To support the latter, we offer a range of electives in module 11, enabling students to explore the options after their bachelor's programme. In consultation with the Board of Examiners, students can select other courses, which prepare them even better for their further development. Finally, module 12 is entirely dedicated to the bachelor assignment. More information on the bachelor assignment is provided in section 3.3.

Table 2.1 *Bachelor curriculum Applied Physics for the academic year 2020-2021. The study load of each module amounts to 15 EC. The numbers indicate the study load for each course.*

	APPLIED PHYSICS			
Year 1	Dynamics and Relativity	Thermodynamics	Electromagnetism and Measurements	Quantum and Geometrical Optics
	5.0 Dynamics and Relativity 4.0 Calculus 1 1.5 Laboratory practice 1 2.0 Progr. and data anal. 1 2.5 Project	4.0 Thermodynamics 4.0 Calculus 2 2.0 Laboratory practice 2 1.0 Progr. and data anal. 2 4.0 Project	5.0 Electromagnetism 2.0 Vector Calculus 4.0 Instrumentation 1.0 Analytical Programming 3.0 Project	5.0 Quantum Matter 3.0 Linear Algebra 2.5 Geometrical Optics 4.5 Engineering Systems
Year 2	Signals, Models and Systems	Waves, Interferences and Probability	Condensed Matter Physics	Continuum Dynamics
	4.0 Signals 4.0 Models 3.0 Project 4.0 Elective (1 of 2): Classical Mechanics Engineering Solid Mech.	6.0 Quantum Mechanics 7.0 Optics 2.0 Hilbert Space	6.0 Statistical Physics 7.0 Intro Solid State Physics 2.0 Partial Differentials Eqs.	6.0 Electrodynamics 7.0 Physics of Fluids 2.0 Num. methods PDEs
Year 3	Minor		Orientation	Bachelor assignment
	Many possibilities (2 x 15 = 30 EC): High Tech Human Touch (HTHT) minors Regular UT minors[3] Teacher training ('leren lesgeven'), crossing borders Study abroad Study at another educational institution Transfer minor (transfer to another master degree progr.)		5.0 Preparation Bach. Assign. Electives (10 EC): Computational Physics Machine Learning Materials Science Remote Control Exper. Soft Matter Physics Technical Optics	Project (15 EC) General Aspects (50%) Physical Aspects (50%)

2.1.3 SETUP AND CONTENTS OF THE MASTER'S PROGRAMME

During the bachelor's, students have become acquainted with the full width of the Applied Physics discipline. The 120 EC master's programme provides students with the opportunity to deepen their knowledge and competences. In addition, we motivate students to dive into one of the specialisations within Applied Physics. Of course, there is sufficient room for everyone to tailor their study programme to match individual ambitions and interests.

The Applied Physics curriculum was changed in 2018, to account for a number of issues and to comply with suggestions from students and teaching staff. Up to 2018, the programme consisted of three tracks (Material Physics, Optics & Biophysics, Physics of Fluids), each with specific track courses. As a result, students within a specific track rarely met each other. In fact, a complaint was that it felt more like we had three separate programmes. In addition, the combination of 50 EC courses, a 20 EC internship, and a 50 EC master assignment, led to a situation in which it was difficult to complete the programme within two years, or eight quarters of 15 EC.

A summary of the current master curriculum is shown in table 2.2. In appendix 2.2 we provide a more elaborate overview. The first year is devoted to courses, while the second year is reserved for the internship and the final assignment. All students take 20 EC of compulsory courses distributed over the four quarters, related to (i) fundamental physics, (ii) mathematical and computational techniques, (iii) engineering physics, (iv) experimental physics and (v) ethical and cultural awareness. These compulsory courses cover the entire scope of the programme. In addition, students choose 20 EC of specialisation courses closely linked to the research of their interest, and 20 EC of elective courses.

In setting up the new curriculum, all research chairs were requested to indicate which specialisation courses are required to enable working in their groups. In the future we aim for specialisation courses linked to the research clusters, rather than specified for every group. This will be part of the further development of the curriculum in the near future.

In the study programme, the specialisation courses are grouped in various categories including Materials courses, Fluid/Soft Matter courses and Optics courses. In close consultation with the study adviser and the research chair each student composes a personal study programme. When a student wishes to pursue an alternative programme that does not fit within the standard rules, an individual master's programme can be composed and submitted for the approval to the Board of Examiners. We think and work in terms of possibilities, rather than strict limitations.

Table 2.2 *Master curriculum Applied Physics for the academic year 2020-2021. Compulsory courses are indicated in bold font. Numbers before each course indicate study load in EC.*

<table>
<tr><th colspan="5">APPLIED PHYSICS</th></tr>
<tr><td rowspan="2">Year 1</td><th>Quarter 1</th><th>Quarter 2</th><th>Quarter 3</th><th>Quarter 4</th></tr>
<tr><td>5.0 Applied Quantum Mech.
10.0 Specialisation/Elective</td><td>5.0 Math. & Num. Physics
10.0 Specialisation/Elective</td><td>5.0 Heat and Mass Transfer
10.0 Specialisation/Elective</td><td>4.0 Small Signals & Detect.
1.0 Eth. & Cult. Awareness
10.0 Specialisation/Elective</td></tr>
<tr><td rowspan="2">Year 2</td><th colspan="2">Internship</th><th colspan="2">Master assignment</th></tr>
<tr><td colspan="2">20.0 Internship
- Research or corporate
- Netherlands or Abroad
Optional: 30 EC (using 10EC electives)</td><td colspan="2">40.0 Final assignment
- in one of the Applied Physics research groups
- optionally also externally (company, research inst.), but under supervision</td></tr>
</table>

The second year comprises the internship and master assignment. Students can choose to focus on fundamental science, e.g. by doing their final assignment in one of our research groups and an internship at a research institute in The Netherlands or abroad, or opt for a more engineering driven route by doing a final assignment in an engineering oriented research group or even a company, combined with an industry-based internship. Of course, combinations of both are also possible.

The main objective of the internship is to experience the future professional field and apply acquired knowledge and skills in an actual working environment. During their internship, students work independently (or as part of a team) on a current, timely challenge. The study load of the internship is set to 20 EC. Students may choose to extend their internship to 30 EC, for example upon request of the hosting company or institute. This reduces their electives to 10 EC in total. Careful planning is even more essential in that case.

The master assignment can be carried out internally or externally, but always under the responsibility and supervision of one of the research groups within the faculty. In the master assignment, students show that they are qualified to make a positive contribution to the field of Applied Physics. More details on the master assignment are described in section 3.3.

2.2 STUDENT LEARNING & TEACHING METHODS

2.2.1 BACHELOR'S PROGRAMME

The Twente Education Model (TOM) is described in section 2.1. Different types of teaching methods are utilised within the bachelor's programme, all in keeping with our educational philosophy, as expressed by our mission, and aimed at achieving the learning objectives of each module in the best way possible:

- **Lecture**: a plenary meeting for the students, primarily intended to convey information.
- **Tutorial**: a plenary meeting for the students to work on assignments, discussions and presentations with a high level of interaction.
- **Lectorial**: a combination of a lecture and a tutorial, which has the advantage that material, which is briefly explained, can immediately be applied in the tutorial.
- **Lab course**: a tutorial offered in the laboratory to carry out experimental work.
- **Project work**: scheduled time to work on the project, which can be either supervised or unsupervised. As projects are often finalised with presentations, these are also scheduled under project work.
- **Guided self-study**: independently or in project teams working with supervision available.
- **Self-study**: independently or in project teams working without direct supervision.

An overview of the distribution of the various teaching methods over the modules, together with actual contact hours is provided in appendix 2.1. A description of the content and learning objectives of different courses is available in the Osiris course catalogue. We also provide this information in the supplemental material.

In each module, a combination of teaching methods is offered. In our lectures and tutorials, for instance, we use principles such as flip-the-classroom and peer learning. Generally, the focus is on interactive teaching methods, with sufficient opportunities for questions and discussions. Active participation and student initiative is encouraged. The relatively small group size with on average 5-8 students in a project group enables lots of interaction and frequent contact between lecturer and students.

2.2.2 MASTER'S PROGRAMME

Student Driven Learning (SDL) remains important in the master's. This is reflected in interactive teaching methods during lectures, tutorials, lab courses and assignments. We consider it important that students take responsibility for designing and executing their own learning process. In that respect, there is a clear distinction between the bachelor's and the master's. This is expressed by the smaller number of contact hours (see also appendix 2.2).

Already in an early stage, preferably even before they start their master's programme, we encourage students to explore their personal interests, and make a tentative planning. Ultimately, we consider the master-apprentice approach essential in the learning process. As soon as possible, we connect students with research groups and staff members, to assist in choosing their specialisation and elective courses, but also in identifying a suitable internship and master assignment.

2.3 RELATIONSHIP BETWEEN THE ILOS AND PROGRAMME CONTENT

2.3.1 BACHELOR'S PROGRAMME

Design, implementation and optimisation of the curriculum is based on the principle of 'constructive alignment'[11]. We aim for a direct relationship between the intended learning outcomes (ILOs), the teaching methods to achieve them, and the assessment methods to measure the degree to which the ILOs have been realised. In table 2.3 we give an

[11] 'Teaching for Quality Learning at University', J. Biggs and C. Tang (2011, McGraw-Hill and OUP, Maidenhead.)

overview of how each module contributes to the ILOs. The size and diversity of a module implies that it will contribute to almost all ILOs, but there is no requirement that it has to contribute to all of them. The three professional roles mentioned earlier, i.e. researcher, designer, and organiser, are reflected quite specifically in several ILOs related to 'skills' and 'organisation' in table 2.3. Therewith the different roles are trained in various modules, with 'design' being most prominent in modules 2, 4 and 5, while 'research' is more prominent in modules 1, 3, 6, 7 and 8.

The individual learning outcomes also relate to some of the learning lines in the curriculum, which run over several and in some cases all modules. Obviously, the cognitive level at which the final qualifications are met increases throughout the programme. In terms of the Blooms taxonomy, the focus in the first year is on application, shifts toward analysis and problem solving in the second year, and to creation and evaluation in the third year.

We further elaborate on the various learning paths in appendix 2.1. From the comparison in table 2.3 it is also obvious that the graduation phase of the bachelor's, i.e. the orientation module 11 and the bachelor assignment in module 12, both contribute to all ILOs. This is not surprising, since these modules combine all aspects of the bachelor's programme and assess the full range of competences.

Table 2.3 *Relationship between intended learning outcomes and the contents of the bachelor's programme.*

Module	1	2	3	4	5	6	7	8	9 &10	11	12
Knowledge											
technical and scientific knowledge	X	X	X	X	X	X	X	X		X	X
overview of the various specialisations and their relevance					X	X	X	X		X	X
Skills											
mathematical, experimental, computational tools to solve problems	X	X	X	X	X	X	X	X		X	X
scientific research methods and identify basic problems	X	X	X	X	X	X	X	X		X	X
solve research/design problems using systematic approach	X	X	X	X	X					X	X
scientific design method and contribute to innovative solutions		X		X	X					X	X
Personal development											
critical, self-thinking, and able to reflect	X	X	X	X	X				X	X	X
applied physics in science, society, and international orientation	X	X	X	X	X	X	X	X	X	X	X
possibilities on labour market or to continue studying					X	X	X	X	X	X	X
decide based on integrity and take responsibility	X									X	X
select, process and evaluate information from different sources	X	X	X	X	X	X	X	X	X	X	X
Communication											
effectively communicate orally and in writing	X	X	X	X	X	X	X	X		X	X
Organisation											
organise and complete project individually or as part of a team	X	X	X	X	X					X	X
attitude to learn and integrate knowledge and skills					X	X	X	X	X	X	X
identify competences for development (life-long learning)					X	X	X	X	X	X	X

2.3.2 MASTER'S PROGRAMME

In table 2.4 the relation between the ILOs and the educational units in the master's programme is summarised. We distinguish between the various compulsory courses, the internship and the master assignment. Details on the specialisation courses is provided in appendix 2.2. As outlined in section 2.1, the compulsory courses account for the fundamental physics, mathematical and computational aspects, engineering approach and experimental approach within the curriculum. Obviously, therewith they contribute primarily to the first two groups of ILOs related to knowledge and skills.

The Ethical and Cultural Awareness course contributes considerably more to the other ILOs, and especially personal development and organisation. Similar to what was mentioned in the bachelor's, the large projects in the second year, i.e. the internship and the master assignment, contribute to all the competences of the graduates.

Table 2.4 Relationship between intended learning outcomes and the contents of the master's programme.

Educational units	Compulsory					Internship	Master assignment
	Applied Quantum Mech.	Math. & Num. Phys.	Heat & Mass Transfer	Small Signals & Detection	Ethitc. & Cult. Awareness		
Knowledge							
technical and scientific knowledge and multidisciplinarity	X	X	X	X	X	X	X
advanced knowledge and understanding applied in sub-area(s)						X	X
Skills							
mathematical, experimental and computational tools to solve complex problems	X	X	X			X	X
scientific research methods and identify advanced problems				X		X	X
identify, formulate, solve research/design problems using systematic approach	X	X	X	X		X	X
scientific design method and contribute to complex innovative solutions				X		X	X
Personal development							
critical, self-thinking, and able to reflect	X	X	X	X	X	X	X
applied physics in science, society, and international orientation					X	X	X
experience with labour market and/or academia after master's						X	X
decide based on integrity, ethical norms and take responsibility					X	X	X
select, process and evaluate information from different sources					X	X	X
Communication							
effectively communicate orally and in writing		X		X		X	X
Organisation							
organise and lead complex project individually or as part of a team				X		X	X
attitude to learn and integrate knowledge and skills			X	X	X	X	X
identify competences for development (life-long learning)					X	X	X

2.4 SCIENTIFIC ORIENTATION

The University of Twente is a research-oriented university. This is also reflected in the research orientation of the Bachelor's and the Master's programme in Applied Physics. All lecturers in the Applied Physics programme are related to a research group. See appendix 2.3 for an overview of our staff and their research area.

Research is integrated in the bachelor modules in various ways. All teachers use examples from their own research in lectures, assignments and also exam problems. Therewith students are gradually introduced to new developments in science, technology and engineering, and incorporate research findings in their project work whenever relevant. In module 3, students rebuild a historical experiment related to electricity and magnetism, while in module 4 they present a poster on a special topic in quantum physics. In modules 6 and 8 the experimental work deals with advanced optical setups and fluid dynamics experiments, respectively. And in module 7, students read, analyse and present a scientific paper in a symposium. All projects have a research character, in which students carry out actual research. A perfect example is provided by a group of students in 2016, who did a first-year project on 'the bottle flip', the results of which have led to a scientific publication[12].

[12] P.J. Dekker, L.A.G. Eek, M.M. Flapper, H.J.C. Horstink, A.R. Meulenkamp, E.S. Kooij, J.H. Snoeijer, A. Marin, 'Water bottle flipping physics', Am. J. Phys. 86 (10), p.733 (2018); doi.org/10.1119/1.5052441

An Applied Physics master student must show that he/she is able to contribute to the body of knowledge within one of the domains of Applied Physics via the master assignment. To prepare for this, research is integrated in master courses as course material, assignments and small projects. In many courses, students study related literature and present the content to their peers. The Applied Physics curriculum constitutes specialisation courses that prepare the student for research in a specific research chair. The content of the majority of the specialisation courses is related to ongoing research.

The master assignment of 40 EC is conducted within a research group at the UT, another university or an institute in The Netherlands or abroad. Students may also choose to do their final assignment at a company. The final assignments are often part of running PhD projects. To guarantee the scientific level, students do their research under supervision of at least one senior staff member, also when the assignment is carried out outside the UT to guarantee the scientific level.

2.5 RELATIONSHIP WITH THE PROFESSIONAL FIELD

Both during the bachelor's and master's programme, students are encouraged to become acquainted with the professional field in many different ways. In recent years, the programme has intensified its collaboration with study association Arago and we have organised job orientation activities together. A good example are the excursions in the second year of the bachelor's programme to companies in the region. These visits are organised in every module and link directly to topics taught in the respective module. They have a two-fold objective: (i) to give students a perspective of where our alumni work, which activities they undertake, what an average workday looks like, and (ii) to develop a sense of appreciation for what the region has to offer. Pertaining to the latter, we noticed that students have a broad view on what their options are far away, but do not see what is right in front of them.

With the introduction of the course Preparation Bachelor Assignment, we specifically focus on job orientation. As part of the course, we motivate students to think about making choices, their own preferences, and the options to explore them. This may involve a career test, but also discussions about scientific and corporate integrity, and presentations by (recent) alumni of the programme.

Finally, we more explicitly present options for bachelor and master assignments. We stress the possibility to do these assignments within a company. The fact that an increasing number of students take up assignments within industry shows that awareness is increasing in this respect.

2.6 TEACHING STAFF

To guarantee the level of academic bachelor's and master's programmes, the availability of highly qualified staff with a scientific background is essential. As shown in appendix 2.3, there is considerable expertise available for education and research in the entire field of Applied Physics. Almost all our lecturers have a PhD degree and participate in scientific research, as full professors, associate professors, or assistant professors. They are often supported by PhD students, who contribute as project tutor, supervisor during tutorials or during bachelor and master assignments.

Applied Physics has a strong community in which students help each other in acquiring knowledge and skills. Study association Arago plays an important role, for example by organising study evenings and other activities, providing feedback and support on quality control. In addition, we employ a large number of senior students who take on the role of teaching assistant, under the supervision of tenured staff, in lab courses, tutorials, and projects. Occasionally, they also assist in development of new courses, experiments or assignments. We encourage students to consider a role as teaching assistant, as it provides the ideal opportunity to further develop knowledge and skills by explaining to others[13].

2.6.1 QUALITY OF THE TEACHING STAFF

All newly appointed scientific staff members must qualify for their educational tasks by attending and finishing the University Teaching Qualification (UTQ). Faculties are charged with the implementation of this policy by providing sufficient time and stimulants. The content of the UTQ programme depends on the lecturer's previous experience in education and is shaped by the lecturer and the faculty's education consultant, in consultation with the programme director. The maximum study load is 250 hours.

Within Applied Physics, 45% of the lecturers have obtained their UTQ or have an equivalent qualification, while 15% have an exemption based on experience in higher education teaching, due to a part-time position or pending retirement. In addition, 30% are actively working on obtaining a UTQ, most of whom we expect to finish within one year. Since 2017, the university also offers a Senior Qualification course (SUTQ), which is relevant for more advanced teaching staff. One staff member within Applied Physics has obtained the SUTQ.

The teaching staff receives support from the Centre of Learning and Teaching (CELT), which is available for all educational questions that arise. At this moment, the teaching capacity suffices for the bachelor's and master's programmes. The expertise, didactic qualities, accessibility and coaching skills of the teaching staff are strongly valued by both bachelor and master students (also see table 2.7 on page 41).

2.7 ADMISSION

2.7.1 BACHELOR'S PROGRAMME

Admission regulations are stated in article 4 of the Education and Examination Regulations (EER) 'Technische Natuurkunde'. The admission of all bachelor students, both students with a Dutch vwo diploma and those with other degrees, is handled by the UT Admission Office[14]. Admission is unrestricted for students who hold a Dutch vwo diploma with an N&T (science) profile. Dutch students with another vwo profile are only admissible if they have completed Maths (Wiskunde B) and Physics (Natuurkunde). Students who completed their first year (propedeuse) at a university of applied sciences (hbo) in Applied Physics, with an average grade of 8 or higher, or students holding a 'hbo-propedeuse' in a technical discipline with vwo-level Maths B, Physics and English are unconditionally admissible.

For all other applicants it is required that their qualifications should be comparable to a Dutch vwo diploma, including Maths and Physics. Since the bachelor's is a Dutch-taught programme (see section 1.4), international students are required to submit proof of their Dutch language proficiency.

We do not set an intake restriction and we do not select based on grades or other criteria. In case the Admission Office is not able to formulate a decision based on the rules and the information provided by the prospective student, or in case an exception seems justified, they will consult the programme director, who decides about admission.

After conditional admission, prospective students are sent a study check questionnaire, which contains questions on prior education, study skills, motivation and high school grades for essential subjects (Physics, Maths, English). It is not compulsory to complete the questionnaire, but strongly encouraged. The programme coordinator reviews all replies and decides ,in consultation with the study adviser, if a conversation with the prospective student is desirable.

2.7.2 MASTER'S PROGRAMME

Admission regulations are stated in article 4 of the Education and Examination Regulations (EER) Applied Physics. The admission requirements of the master's distinguish between different groups of students depending on their prior education. Students from a Dutch university holding a BSc degree in (Applied) Physics are unconditionally admissible. In all other cases, proof of admission must be issued by the admission board (EER art. 3), possibly stating extra requirements. To be admissible, students from a Dutch university holding a bachelor's degree other than (Applied) Physics may need to complete a pre-master's programme, depending on their prior education[15]. Students with an

[13] 'Het student-assistentschap als deel van de opleiding', S. de Bone, G. Daling, NTvN 83 (12), p. 412 (dec. 2017). See also supplemental information.

[14] See utwente.nl/en/education/bachelor/admission/ for more information.

[15] For details, see doorstroommatrix.nl/

international degree in either (Applied) Physics or related are admissible with additional conditions, after approval of the admission board.

2.7.3 PRE-MASTER'S / DEFICIENCIES

Students holding a bachelor's degree in Applied Physics or Electrical Engineering from a university of applied sciences (hbo) are eligible for admission after completing a pre-master's programme of 30 EC. The pre-master's programme offers courses in mathematics and physics, but also involves academic research skills, to assess suitability for the master's programme. Students can take the pre-master's either after obtaining their hbo degree, or as part of their minor (KiesOpMaat, KOM).

2.8 STUDENT INTAKE

2.8.1 BACHELOR'S PROGRAMME

The number of incoming students over the past decade is shown (open symbols) in figure 2.1(a). Most students enrol immediately after finishing high school (vwo). About 8-10 students have a different background, i.e. come from hbo or another academic programme. Following an increase in the beginning of the last decade, the intake fluctuates between 65 and 85 students. Typically, 15-20% of our first-year students is female, while on average 5-10 students enrol in the double programme Applied Physics/Applied Mathematics.

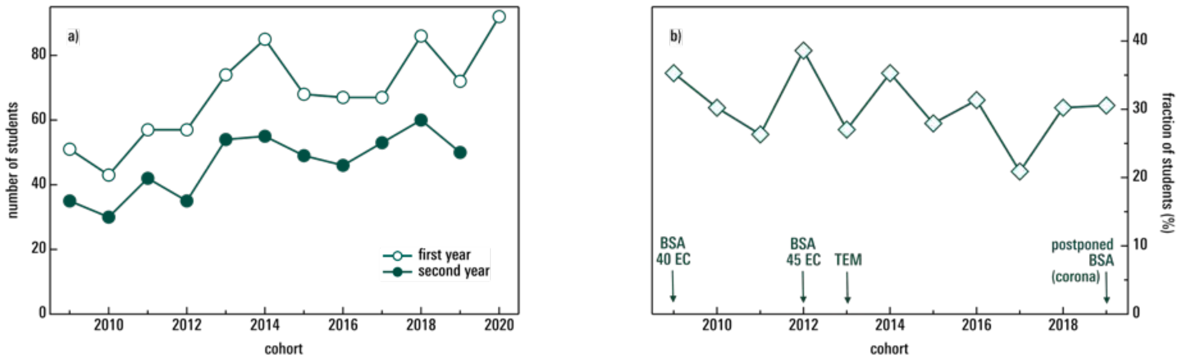
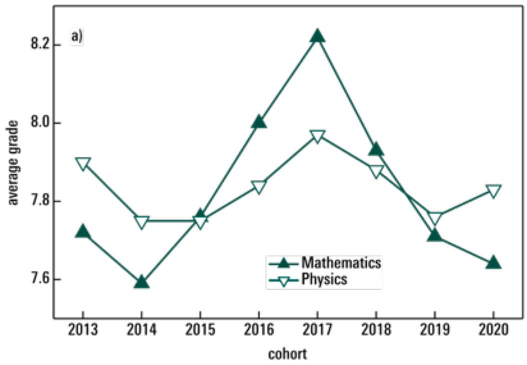


Figure 2.1 *(a) Number of students entering the bachelor's programme (open circles) and continuing to the second year (filled circles) over the last ten years. (b) Percentage of students that discontinue in or at the end of the first year.*

Also shown in figure 2.1(a) are the number of students per cohort that continue to the second year. The percentage that does not continue is plotted in figure 2.1(b). The first-year dropout rate has been rather stable over the past years, fluctuating around 30%, with a positive exception of 21% in 2017. The introduction of the binding study advice (BSA) (40 EC in 2009, 45 EC in 2012) and TOM (in 2013) does not seem to have had any effect on the dropout rates.

The average vwo grades for mathematics and physics (figure 2.2) have proven to be an important indicator for study success, both in the first year as well as in subsequent years. In general, the majority of students with a 7.0 or higher have a good chance of successfully finishing the first year, and subsequently obtaining a bachelor's degree within three to four years. The Maths grade is the most reliable indicator. Interesting to note in this respect is the fact that in 2017 the relatively low dropout rate coincides with the relatively high average Maths grade of 8.22.



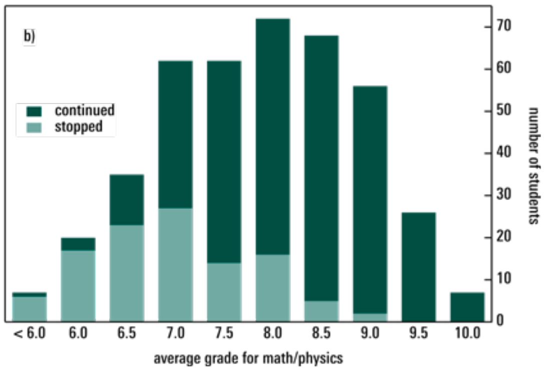


Figure 2.2 *(a) Average grades for mathematics and physics in recent years. (b) The number of students continuing (dark) onto the second year and those discontinuing (light) during or at the end of the first year, in relation to the average grade for Maths and Physics. Results in panel (b) are based on 2013-2018 cohorts.*

2.8.2 MASTER'S PROGRAMME

The number of incoming students in the master's programme has fluctuated considerably in the past, but has been relatively stable over the last years. From table 2.5 it follows that the influx of students from UT bachelor's programmes is traditionally high. Most of these students transfer directly from our own bachelor's programme. Evaluations have shown that students with an Applied Physics degree from the University of Twente only leave for another university if, for example, the specialisation of their choice is not offered in Twente.

The number of international students is relatively low. Several reasons can be considered. First of all, there is no international influx in the bachelor's. Also, we do not have double-degree programmes with other institutes in the world. But most important is the fact that Applied Physics in general is not unique. As such, there are numerous competing programmes across the globe. Nevertheless, many students are interested to join one of our top research groups, and do so when continuing with their PhD.
On average, about 5 students with a hbo-degree enter the programme annually after completing the pre-master's programme. We see an increase of the interest from hbo students. Together with our marketing and communications department we strive to increase the number of applicants with a hbo degree. Finally, the relatively large number of incoming students in 2020 with an 'other' prior education is due to the 'zachte knip' in that year related to the COVID-19 crisis. Many students pursuing an experimental bachelor assignment were allowed to postpone this, and provisionally enrol in the master's programme. As such, they did not yet obtain a bachelor's degree.

Table 2.5 *Number of incoming master students in the last eight years.*

Cohort	2013	2014	2015	2016	2017	2018	2019	2020
BSc degree UT	18	48	15	38	36	37	35	15
BSc degree non-UT (NL)	1	1	0	1	1	0	2	3
hbo degree	3	8	4	2	5	4	6	5
Int. BSc degree	1	1	7	2	6	5	2	2
Other	0	0	0	0	0	2	0	22
Total	23	58	26	43	48	48	45	47

2.9 FEASIBILITY, STUDY LOAD AND EXCELLENCE

This section describes to what extent the bachelor's and master's programmes can be completed within the nominal study time. In addition, we briefly review excellence programmes.

2.9.1 BACHELOR'S PROGRAMME

Module teams, in consultation with the programme staff, take care that the study load is manageable, and that activities and assessment are well distributed over the ten weeks of the module. Most modules are perceived as feasible, as expressed by students during the module evaluations. In some cases, the study load is not in line with the number of ECs indicated for each course, but the overall load in every module is doable.

Feasibility also relates to the time students take to complete the bachelor's programme. We consider the programme doable when an average student (vwo grade 7.5 for Maths and Physics), who spends 40 hours per week studying, is able to finish the programme within three years. In figure 2.3(a) the bachelor performance is represented. The percentage of nominally graduating students is relatively low at 30% average. In comparison, the percentage of students graduating in four years is substantially higher, averaging at approximately 60%. This is comparable to comparable programmes nationwide. Many of our students are active either within or outside the Applied Physics programme, e.g. in a board, committee or one of the university's multidisciplinary student teams. These activities lead to a prolonged study duration, but they provide the student with valuable experience in their development as an academic professional, which we strongly encourage.

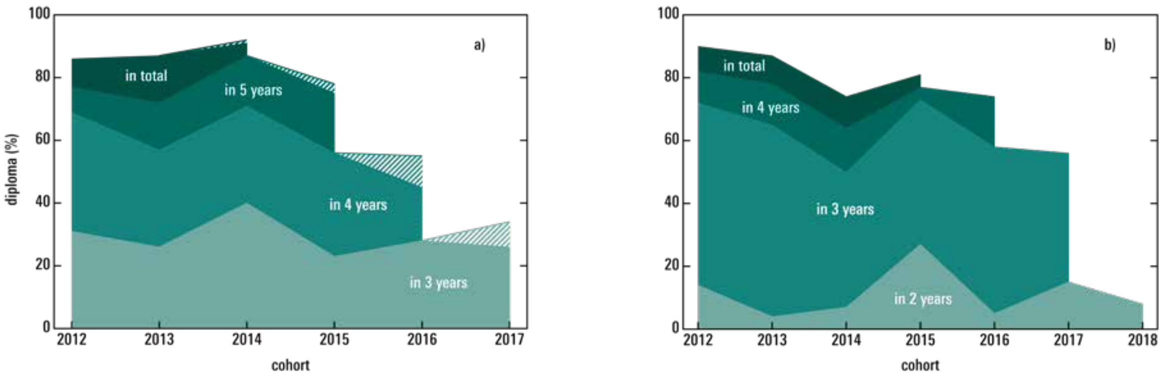


Figure 2.3 *Performance as expressed by the study duration per cohort in the (a) bachelor's and (b) master's. The number of students obtaining their diploma is relative to the number of students continuing onto the second year. The shaded areas in (a) indicate the students who did not finish their bachelor's programme in 2020 due to restrictions resulting from the COVID-19 crisis. These students postponed their experimental bachelor assignment, while already taking master courses.*

In the last 4 years, we have spent considerable effort to reduce the time students spend on their bachelor assignment. We encourage students and supervisors to aim for a nominal duration of 10 weeks full-time. This has been effective in that most students now finished their bachelor assignment within three months. However, it has not led to an increase of the percentage of students finishing their bachelor's programme in three or four years.

2.9.2 MASTER'S PROGRAMME

The study load in the master's has been discussed extensively between teaching staff, professors and programme staff. The change of the curriculum in 2018 has led to an increased awareness to not overload students. This has paid off judging from the results of the NSE (2019), in which the Applied Physics programme scores a 3.9 (on a 5-point scale) on study load. Also in semi-annual panel meetings, students indicate that the overall study load is very reasonable. In the alumni survey (appendix 4.1) our alumni indicate that the study load is high, but that this is part of the challenging character of the programme and as such contributes to their professional development and the value of their master's degree.

From figure 2.3(b) it follows that the percentage of students who finish the master's programme in nominal time is very low. Only 10-20% obtain a diploma in 2 years. But 60-70% finish the programme in 3 years. Student activism only partly accounts for this delay. According to students, the delay originated from the fact that until 2018 the curriculum consisted of 50 EC courses, 20 EC internship and 50 EC final assignment, which made it difficult to complete the programme in 2 years. Analysis showed that a majority took 2 years and 1 quarter. To resolve this, the programme, as of 2018, encompasses 60 EC courses, 20 EC internship and 40 EC final assignment. We hoped to see the first effects of this in 2020, but the COVID-19 crisis has also led to delays for many students, due to inaccessibility of laboratories and/or difficulties with internships abroad.

2.9.3 EXCELLENCE PROGRAMMES

Feasibility often refers to delay and longer than nominal study delay. Some of our students are up for an extra challenge, and eager to obtain more from their bachelor's programme. There are various options. In the bachelor's we offer a dedicated double programme with Applied Mathematics. By smartly combining electives and shared courses, students do approximately 20 EC each quarter and complete a 220 EC programme to obtain an Applied Physics and an Applied Mathematics degree. In the master's, more students pursue a double programme, with many options including Applied Mathematics, Biomedical Engineering, Computer Science, Nanotechnology or Education and Communication in the Exact Science. Together with the students we investigate which programme suits them best.

Bachelor or master students in search for more depth but not attracted to a double programme, can consider a plus programme. By taking additional courses, they can expand into specific research fields such as Nanotechnology, Biophysics and Computer Science. When students complete at least 15 EC extra, this is mentioned on their diploma supplement. Students who are not up for an additional challenge, can consider including these courses in their minor as part of the regular programme.

The options mentioned above provide in-depth opportunities. To develop more broadly, the University of Twente offers an honours programme for outstanding and motivated bachelor and master students, who want to challenge themselves both academically and socially. This programme brings together students from different disciplines and has a distinct 'High Tech Human Touch' profile. It provides a unique combination of technology, engineering and social sciences.

2.10 FACILITIES

2.10.1 COACHING AND COUNSELLING

Student support within Applied Physics already starts before students enrol in the programme. During introduction activities such as the Open Day, prospective students are given the opportunity to ask questions to the programme staff, study advisers and students. This helps to decide whether Applied Physics is the right choice for them. As explained in section 2.7, a (voluntary) study check questionnaire is part of the admission process. Based on this, students can make an appointment with the study adviser for further assistance in making their final decision about starting the programme. In case of special circumstances, such as a disability or chronic disease that may influence their studies, a student is invited to discuss with a study adviser before their arrival at the university.

University life starts with the introductory Kick-In, during which students are informed about what they can expect from staff and teaching staff. Likewise, we tell students what we expect from them. During the Kick-In, students meet in so-called 'doe-groepen', i.e. groups of first-year students guided by older year students to get familiar with the University of Twente and the programme. 'Doe-groep' members often stay close during their entire study period and are friends for life.

Study advisers are responsible for student support. They monitor study progress, study planning, and assist with arrangement in case of special circumstances. Also, study advisers act as coach in orienting on future career steps, including the choice for a master. At regular intervals, students are invited to meet with study advisers. First-year students with a negative or neutral preliminary recommendation on continuation of studies are monitored more intensely. Alternatively, students can request a meeting using the online planning tool. At university level various facilities are available related to student advice and counselling.

Besides support from the programme, student guidance also takes place within the courses and during their final assignments. Both in the bachelor's and in the master's programme, lecturers have an open-door policy. Besides this, many staff members have a role in one or more of the projects in the bachelor's programme and/or supervise individual bachelor and master assignments.

In 2020 we initiated tutoring within the Applied Physics programme. All 'doe-groepen' have been assigned a tutor, a professor or senior teacher, with whom they meet on a regular basis, typically once a week. Discussions may be on any topic related to academic and/or personal development, either physics related or otherwise. Tutors are distinctly different from mentors, and do not interfere with individual study progress or planning. This remains the responsibility of the study advisers.

2.10.2 INFORMATION SUPPLY

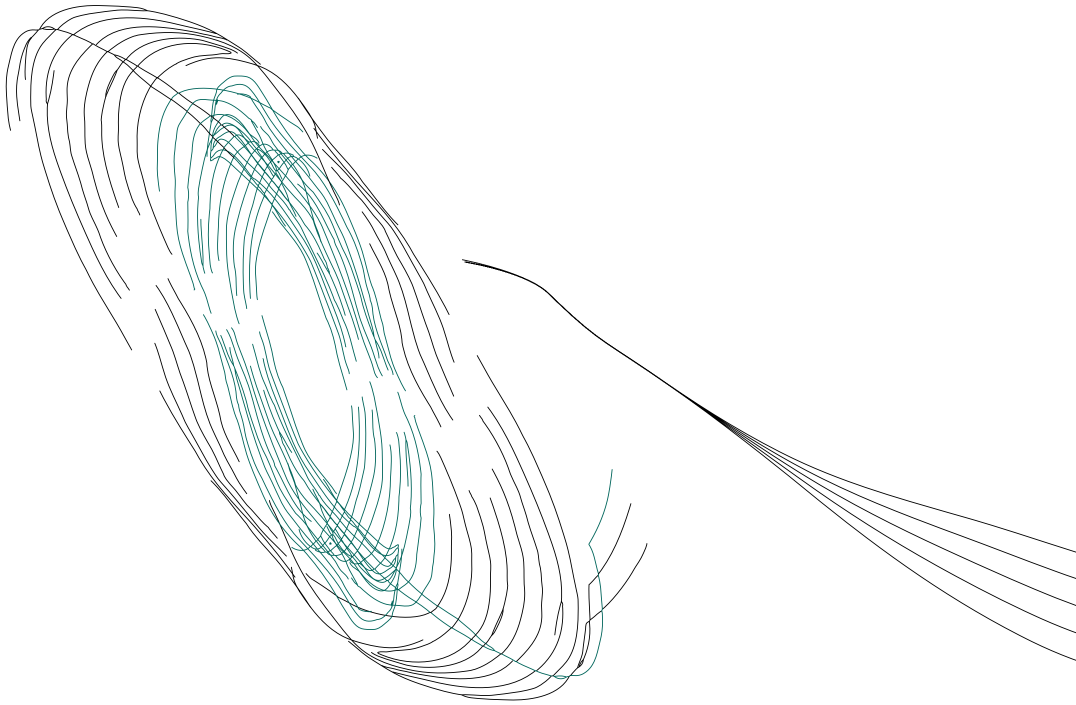
For upcoming and registered students, programme information and information on rules and regulations is available via the university and faculty websites. For registered students, details about the courses, tests and assessments are published in the course catalogue (Osiris) and the electronic learning environment (Canvas). Results of partial tests are published in Canvas, and final results are recorded in the Student Information System (Osiris). Registered students receive a university email account that is used for formal communication, for example related to the binding study advice (BSA) and decisions of the Board of Examiners. In addition, before the start of every quarter, the programme staff sends specific information mails to all cohorts.

Although most information is readily available on the website or on Canvas, regular meetings are organised to provide relevant information on for example the internship, studying abroad, minor options, etc. Furthermore, at the start of every quarter, the programme director joins the kick-off meeting of all modules and the compulsory master courses. In a short presentation the position of modules within the curriculum is highlighted, together with an overview of the research activities of teachers and their research groups. Relevant information on the programme can also be shared and explained. Lecturers, study advisers, the programme coordinator, and the programme director, exchange coordinator and internship coordinator are available for consultation for those having questions, both via email, by telephone and in person.

2.10.3 PROGRAMME SPECIFIC FACILITIES

The Applied Physics programme is based in the Carré-building, connected to the recently built Homebase. This 'beating heart' of the Science & Technology faculty was primarily made possible through funds originating from the quality agreements. It is home to the Advanced Technology, Applied Physics and Chemical Science & Engineering programmes and their study associations. This is where study association Arago is located, and where students can socialise and study in the available project rooms or in the communal study area.

Various facilities are available, including lecture halls, study rooms, ICT facilities and the library. For performing experiments and lab courses, a range of state-of-the-art laboratories is facilitated by Student Laboratories Twente (SLT), such as the student labs on the 4th floor of the Carré-building. The student lab facilities are excellent and provide a unique addition to our teaching activities. Also available is a self-service workshop that offers students facilities for simple manufacturing (drilling, sawing, milling) with metals and plastics, the Designlab and 3D printing facilities. The research groups in the field of Applied Physics are housed (mainly) in the Carré- and Meander-buildings as well as the MESA+ Nanolab. Students working on their final bachelor or master assignment, are provided with an office space and facilities within the research group. Generally, the direct working relationship between research staff and students is perceived as motivating and productive.



2.11 QUALITY ASSURANCE

Within Applied Physics there is a long tradition of quality assurance and monitoring of student satisfaction. The actual quality assurance system has been implemented according to the PDCA-cycle (Plan-Do-Check-Act) and consists of four control loops at different hierarchical levels (see also appendix 2.4). Basic and essential is the direct feedback between student and teacher during classes and the discussion between students, teachers and staff in the panel meetings. Secondly, feedback from the quality assurance committee is crucial to having a strong Act-phase. Essential in this phase are the activities of the programme staff with an important role for the programme committee advising on the module and course evaluation reports.

In table 2.6 the evaluation activities with respect to various themes in the bachelor's and master's programme are listed. Programme staff keeps track of the quality assurance activities and makes sure that action points are implemented. The outcome of the evaluation cycles is made available to students and teachers via a Canvas site specifically for quality assurance. Furthermore, we encourage teaching staff to share any changes they have made to their courses following student evaluations. Finally, in the module introductions by the programme director implementation of improvement suggestions are also mentioned.

The master's programme is evaluated on a course level by surveys, including questions on level and clarity of assessment. The aim is to evaluate all courses at least once every three years if participation is sufficiently high, i.e. at least 15 students.

__Table 2.6__ Evaluation activities of the bachelor's (top) and master's (bottom) programmes. More details are provided in appendix 2.4.

Themes in the bachelor	Module evaluations				Curriculum evaluations		
	Module survey	Student panel meeting	Lecturer panel meeting	BSc assignment survey	Exit survey	National Student Survey (NSE)	Accreditation assessment
Module (content, position in curriculum, entry level, tests & assessment, didactical form)	X	X	X	X			X
Feasibility & study load	X	X	X	X	X	X	X
Performance indicators			X				X
Curriculum (broadness, depth, coherence, final qualifications)					X	X	X
Teaching staff	X	X	X	X		X	X
Facilities		X	X	X	X	X	X
Student advice & counselling		X			X	X	X
Frequency	Each module			Annually			6-yearly

Themes in the master	Course evaluations				Curriculum evaluations		
	Course survey	Programme panel meeting	Internship survey	MSc assignment survey	National Student Survey (NSE)	National Alumni Survey (NAE)	Accreditation assessment
Courses (content, position in curriculum, entry level, tests & assessment, didactical form)	X	X	X	X			X
Feasibility & study load	X	X	X	X	X	X	X
Performance indicators							X
Curriculum (broadness, depth, coherence, final qualifications)					X	X	X
Teaching staff	X	X	X	X	X	X	X
Facilities		X	X	X	X	X	X
Student advice & counselling		X			X	X	X
Frequency	1- or 3-yearly	Semi-annually	Annually				6-yearly

The compulsory courses are evaluated every year. Teachers may ask for additional evaluation, for example after they have implemented substantial changes to their course. Additionally, a student panel meeting is organised twice a year, focusing on the overall programme. The programme director chairs these meetings enabling direct contact and feedback from students to management. Whenever applicable and relevant, the programme staff discusses with teachers on further steps to be taken. The Advanced Fluid Mechanics course provides a good example where the combination of survey results, a panel discussion and a constructive attitude among teachers and students has led to an increase of overall appreciation from 5.0 to 8.9 (on a 10-point scale) in only two years.

2.12 REFLECTION

In this chapter we have shown how the bachelor's and master's programme are organised. As mentioned in the Introduction, qualification, socialisation and personification are the pillars of modern academic education. To achieve these goals, the curricula are aligned with the ILOs. They were presented in terms of programme contents, learning activities, scientific orientation, and the link to the professional field. Sufficient human resources, i.e. teaching staff, study advisers and support staff, are available to create an optimal learning environment. This guarantees the qualification aspect. For socialisation and personification, we build on the close contact between students among themselves and with teachers. Also, we rely on and actively collaborate with study association Arago, especially for the socialisation and personification aspects.

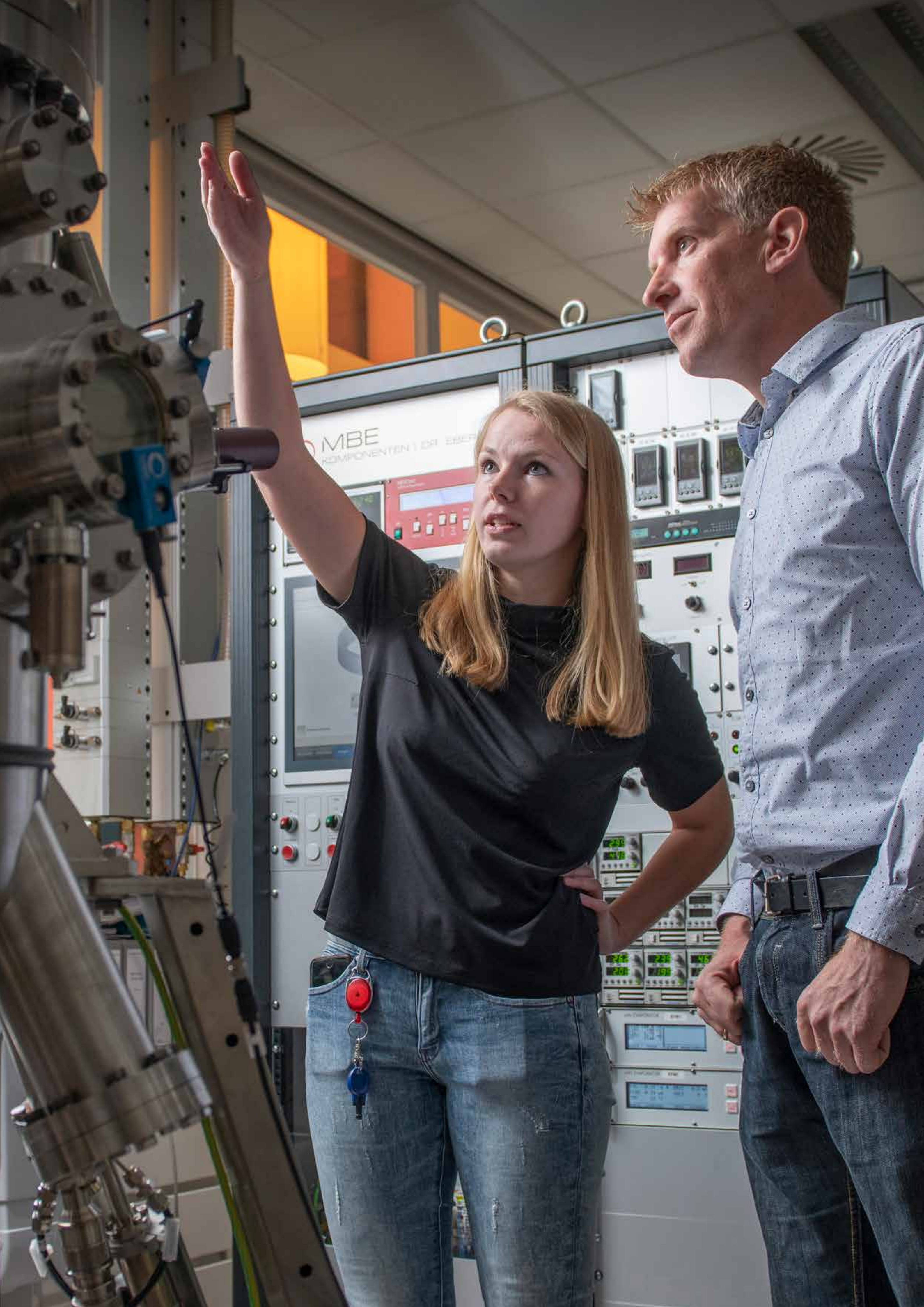
As highlighted in the Introduction, we strongly value the opinion of students, and their input for the programmes we offer. Important feedback comes from evaluations but also the National Student Survey (NSE). In table 2.7 we summarise the scores of the past years on aspects relevant to the teaching and learning environment. The results show a consistently high appreciation of students for our programme. We specifically mention the excellent scores for academic guidance and counselling. Similarly, the expertise, didactic qualities, accessibility and coaching skills of the teaching staff is very much appreciated.

Table 2.7 *Student appreciation (on a scale of 1-5) on various aspects relevant for this standard, derived from the NSE (2015-2019).*

Student appreciation	Bachelor					Master				
(on a scale 1-5)	2019	2018	2017	2016	2015	2019	2018	2017	2016	2015
Content	4.32	4.24	4.19	4.05	4.08	4.32	4.11	4.14	4.21	4.23
Group size	4.67	4.56	4.50	4.33	4.31	4.43	4.35	4.50	4.52	4.62
General skills	4.18	4.19	4.11	4.05	4.03	4.23	3.98	4.05	4.09	4.11
Academic skills	4.36	4.35	4.28	4.19	4.19	4.38	4.06	4.23	4.24	4.26
Preparation professional career	3.77	3.68	3.58	3.47	3.43	3.73	3.49	3.39	3.48	3.66
Study load	3.76	3.77	3.78	3.56	3.59	3.85	3.66	3.63	3.54	3.75
Teaching staff	4.20	4.22	4.12	4.05	4.11	4.33	4.07	4.14	4.17	4.25
Academic guidance/counselling	4.39	4.37	4.22	4.09	4.03	4.27	4.06	4.03	4.06	3.89
Learning facilities	4.23	4.18	4.16	4.05	4.04	4.28	3.99	3.98	4.00	4.03
Availability of information	4.12	4.08	3.94	3.66	3.58	4.25	4.03	3.75	3.84	3.92
Quality evaluation	4.45	4.40	4.32	3.94	3.75	4.52	4.14	3.96	3.75	3.76
Pursuit of excellence	4.12	4.21	4.04	-	-	4.29	4.09	4.08	-	-

Of course, there is always room for improvement. In that respect it is encouraging to note a persistent increase of most scores in the bachelor's, reflecting our continuous efforts to improve after implementing the Twente Education Model (TOM) in 2013. The scores for the master's show a different trend. The strong focus on bachelor education within the University of Twente was accompanied by less attention for the master's, leading to a slight decrease in the period 2015-2018. But we are glad to note that after the curriculum change in 2018, numbers have risen considerably in 2019 on all aspects.

Finally, the last year has been a serious test on our flexibility and resilience, as we had to adapt to the rapidly changing conditions related to the COVID-19 virus. Relevant aspects in that respect are described in appendix C. What the future will bring, we cannot foresee. But obviously, we will continue to optimise our education and guarantee a sustainable programme. In the last chapter of this report, we will look forward, describe our ambitions and present some plans for the future.


MBE

3. ASSESSMENT (STANDARD 3)

This chapter outlines how assessment is organised in the bachelor's and master's programmes. First, vision and policy are presented, including the various responsibilities. Subsequently, we outline the organisation of assessment along the PDCA cycle, ending with an analysis of the assessment of final projects. To conclude, we briefly reflect on this standard.

3.1 VISION, POLICY AND RESPONSIBILITIES

Student assessment aims at establishing if students acquired all knowledge and skills that are defined in the intended learning outcomes. It provides the proof needed for the board of examiners to award the diploma. Additionally, by means of assessment the student obtains feedback on his/her progress; as such, assessment is part of the learning process.

To explain the vison on assessment, the Applied Physics programme defined an assessment policy, i.e. a coherent set of measures and provisions, which the programme takes to monitor, stimulate and improve the quality of testing and examination. In 2016, the University of Twente defined its testing policy under the title 'Quality Assurance Framework for Student Assessment'[16]. The framework focuses on two perspectives of testing: (i) the organisation of the responsibilities at programme, course and test level; and (ii) the quality control through implementation of the PDCA-cycle at programme level in relation to the specific criteria for tests: transparency, validity and reliability.

Based on the principles in the framework of the University of Twente, the Applied Physics programme defined a more detailed framework at programme and sub-programme level (table 3.1) to support its assessment policy, specifying requirements A-F:

A. Topics of examination of a course should be consistent with its learning objectives.
B. Form of assessment should be derived from and in accordance with the learning objectives and didactical concept of the course.
C. Scheduling of all assessments should be in balance with the study load.
D. Examiners should be qualified (section 2.6.1).
E. Regulations and the way the cutting score will be determined should be clear and published in advance.
F. The quality, execution and evaluation of assessment must be monitored and required actions for improvements taken.

Crucial in the assessment policy are requirements A and B to assure that the assessments are:

- **Transparent**: the forms and topics of assessment should be clear for students,
- **Valid**: the assessment forms should be in line with the learning objectives and the teaching methods,
- **Reliable**: the assessment should measure consistently.

Responsibilities are defined according to the requirements stated in the Applied Physics assessment framework. The framework describes (i) the products which support testing and assessment, i.e. regulations, protocols and student information, and (ii) the responsibilities regarding these products to cover the abovementioned requirements A to F. In table 3.1 the products and the related responsibilities are summarised. Transparency, validity and reliability are assured by a combination of assessment plans, examples of recent exams and additional rules for lecturers to ensure a transparent assessment preparation, execution, correction, analysis of the results and evaluation of the attained educational objectives. The Education and Examination Regulations (EER) and the procedures of the Board of Examiners (BoE) are aligned with the assessment policy. All tasks and procedures of the BoE are described in its

[16] 'Quality Assurance Framework for Student Assessment UT', UT Strategy & Policy Dept., December 2016.

internal rules[4], including the tasks mandated to the secretary. The EER and Rules of the Board of Examiners are published on the website of the programme.[17]

***Table 3.1** Assessment framework based on requirements for testing (products in bold).*

Assessment policy		Responsibilities		
		Programme management	Lecturer / Examiner	Board of Examiners (BoE)
A	Topics of examination	• issues **intended learning outcomes** and **curriculum**	• defines the **learning objectives** for each subject	• checks whether intended learning outcomes are fulfilled
B	Form of assessment	• proposes an **assessment protocol** for written exams • issues collection of recent exams (by Arago)	• defines **course information** and **assessment plan** • provides **recent (trial) exams** + **solutions** + **assessment standards**	• advises on assessment plan (desired) • advises on modifications to assessment plan (compulsory)
C	Scheduling	• determines assessment planning	• proposes assessment planning	• advises on assessment planning
D	Examiners	• facilitates and monitors training	• follows additional assessment training (if desired)	• appoints examiners • approves AP **staff overview** (semi-annually)
E	Rules and regulations	• establishes additional **EER regulations**	• complies with EER and Rules BoE	• establishes **Rules BoE**, including internal rules • checks compliance EER and Rules BoE
F	Quality assurance	• issues **test and assessment evaluations** based on surveys, test results and panel evaluations	• acts on **improvement points** originating from surveys and panel evaluations	• reacts on impediments • assesses reports from module coordinators • issues **annual report**

Before the start of every academic year, the programme management presents the curricula and study programmes for the coming year. Together with approval of the study programme, the Board of Examiners also gives its consent to the examiners that are appointed for each course by the programme management. These examiners are also responsible for assessment and determining the test results (in accordance with article 7.12c of the WHW). In addition, twice a year the overview of Applied Physics staff is updated, including their possible roles as chair or reference member in bachelor and master graduation committees and as internship supervisor. A guideline is that the roles can only be filled by permanent staff members or staff with a tenure track appointment.

As mentioned, the UT test policy describes how the PDCA-cycle is implemented to ensure assessment quality. The following parts can be identified, on which we elaborate below for the bachelor's and the master's programme:

- **PLAN**: drawing up the module or course plan, including the assessment plan and course information.
- **DO**: executing the module or course according to plan, with different assessment methods.
- **CHECK**: evaluating the module or course, including the assessment.
- **ACT**: identifying and implementing changes in line with the evaluation results.

3.2 IMPLEMENTATION OF ASSESSMENT

In the bachelor's and master's programme all study units (courses and parts of modules) are examined separately. The combined results of all course examinations make up the study programme of a student, which is evaluated by the

[17] bachelor: utwente.nl/tn | master: utwente.nl/ap

board of examiners to verify whether the intended learning outcomes have been met. Leading in the design of the assessment programme is the principle of ‘constructive alignment’, i.e. the learning objectives determine the teaching methods and the assessment methods relate to the teaching methods and the learning objectives. In more detail the requirements for the design of tests within Applied Physics are:

- a balanced mix of teaching and assessment methods that is coherent and leads to the realisation of the specified intended learning outcomes,
- a structure of sequential tests in accordance with the learning trajectories to stimulate the learning process of a student along those learning trajectories,
- a combination of tests to ensure a valid and reliable assessment of the (usually complex) competences,
- a mix of group and individual assessments and grading,
- a balanced spread of the tests through the curriculum and through each module.

In line with these requirements, different assessment forms are used within Applied Physics; a further explanation is provided in appendix 3.1. Generally, the final grade of an examination is based on one, or a combination, of these methods. We consider it important to apply various assessment methods for three reasons. First of all, we want to confront our students with a wide range of experiences resembling the professional practice. Second, students generally have different learning styles and therewith study success will benefit from a balanced variation in activities and tests. Finally, it ensures that fundamental knowledge, skills, attitude and more complex behavioural competences are all assessed, both separately and combined with each other.

It is important to assess whether every individual student meets the final qualifications of the programme. This includes aspects of teamwork, which we consider a crucial competence for a graduate in an engineering discipline, and thus also for an Applied Physics graduate. A balanced combination of group and individual assessments guarantees that the Applied Physics graduate meets the full breadth of intended learning outcomes.

3.2.1 BACHELOR’S PROGRAMME

As discussed with standard 2, the curriculum of the bachelor’s programme is subdivided into thematic modules, in which different subjects are coherently taught and assessed. Prior to the start of every module, a module plan is compiled by the programme coordinator in consultation with the module coordinator. The content and learning objectives are described in the course information, which is made available via the course catalogue in Osiris. Additionally, an assessment plan is compiled and discussed in the preparatory meeting, which is ideally attended by all teachers in the module and chaired by the programme coordinator. The assessment plan describes the different parts of the module, and for each study unit the designated examiner, number of ECs, primary language of instruction, forms of testing, minimum grade (optional) and relative weight in the overall examination, and teaching staff involved. In appendix 3.2 examples of assessment plans for modules 1 and 6 are shown. The assessment plan is sent to the board of examiners for advice, after which it is implemented by the programme director. To ensure transparency, the established assessment plans are published on the website of the programme[17].

All modules have a comparable structure for testing contents, skills and attitude. Theoretical courses are mostly assessed with individual written exams. In several modules, (optional) homework assignments are provided, primarily intended as formative assessment; grading may lead to bonus points for the final examination. Projects are generally assessed with multiple forms like a report, a presentation or a video. To avoid ‘free riding’, an individual component is often part of the project assessment. Table 3.2 provides an overview of the different assessment methods used within the Applied Physics bachelor’s programme; a more detailed explanation about these assessment methods is given in appendix 3.1.

Execution of the module proceeds according to the module plan. During the module, grades for tests are communicated to students within the digital learning environment (Canvas). In addition, grades are assembled by the programme coordinator, to provide the programme staff with an up-to-date overview on progress of individual students. Furthermore, intermediate feedback provides valuable information on what happens within the module, also related to assessment. In case of problems, quick action can be taken, e.g. study adviser contacts students, or programme management discusses with teachers.

Table 3.2 *Overview of assessment methods in the Applied Physics bachelor's modules (i = individual, p = pairs, g = group). Also included are results of student evaluations on assessment, i.e. clarity of assessment criteria and suitability for fair assessment of knowledge and skills, for three consecutive years (on a scale of 1-5).*

	Written exam	Oral exam	Presentation	Demonstration	Assignment	Lab journal	Report/essay/paper	Poster	Video/website	Contribution/effort	clarity			suitability		
											2017-2018	2018-2019	2019-2020	2017-2018	2018-2019	2019-2020
Module 1	i		g		p	i,p	g			i	3.9	4.1	3.7	3.9	4.1	3.8
Module 2	i	i,g		g	p,g	i	p,g			i	3.8	4.0	3.6	3.8	3.9	3.5
Module 3	i		g	g	i,g	i,p	i,g			i	3.7	3.5	- *	4.1	3.5	- *
Module 4	i		p	p	i	p	g	g			3.1	4.0	3.3	3.1	4.0	3.4
Module 5	i	p		g		p	g		g	i	3.6	2.6	3.5	3.5	2.8	3.8
Module 6	i		p		i,p	p	g				3.7	4.2	4.2	3.7	3.7	3.9
Module 7	i	i	i		i,p		g				4.3	3.5	- *	3.5	2.9	- *
Module 8	i	i	g		i,p	i			g	i	3.6	4.2	4.1	3.9	4.3	3.8
Module 11**			i		i		i			i	-	-	-	-	-	-
Module 12			i				i			i	3.7	3.8	4.2	4.2	4.1	4.4

** Due to the transition to online education in March 2020, student evaluations of modules 3 and 7 contained slightly different questions. Appreciation on (online) assessment for the modules was 6.6 and 7.5, respectively, on a 10-point scale.*
*** Module 11 consists of various electives, each with different testing methods. Only the assessment methods of the compulsory Preparation Bachelor Assignment course are included; assessment is not included in the questionnaire.*

With the implementation of the Twente Education Model (TOM) in 2013, a module assessment meeting was scheduled at the end of each module, during which results of all students were discussed and the final grade was determined following the assessment plan. During these meetings, chaired by the module examiner (usually also the coordinator), all examiners of the module parts were present as well as the programme staff. After the meeting, all grades of the module parts and the final grade were recorded in the study information system (Osiris). With the development of TOM 2.0 in 2020, these meetings will no longer take place.

As part of the didactic principle of TOM, students are encouraged to study entire modules as coherent units; central rules and regulations reflect this. Until September 2020, modules were considered as a single study unit, awarded with a single grade only after the entire module was completed. Sufficient grades, i.e. a minimum of 5.5, for module parts remain valid; students only needed to redo the parts they did not pass. Within the Applied Physics programme, the individual interest of every student is important, and a custom-made, flexible study planning is discussed with the study advisers. In 2020, further development led to TOM 2.0. The main difference relates to administration; programmes choose whether a module is (i) integrated, i.e. a single study unit, or (ii) coherent, with all module parts being study units. Within Applied Physics all modules are coherent, and ECs are awarded for every module part after completion with a 5.5 or higher.

Every bachelor module is evaluated, as outlined with standard 2. Surveys and panel discussions include questions on transparency, validity and reliability of tests; results are included in table 3.2, demonstrating overall appreciation for module assessment.

3.2.2 MASTER'S PROGRAMME

As described with standard 2, the master curriculum consists of compulsory courses, specialisation courses and electives in the first year, followed by an internship and master assignment in the second year. The assessment is organised similar to that in the bachelor, but more on a course level. Most of the assessment methods outlined in appendix 3.1 are also used in the various master courses. To ensure assessment quality, the PDCA-cycle is implemented on a course level (see also section 2.11).

The preparatory phase is initiated before the start of the academic year. The programme coordinator collects the course information, i.e. content and learning objectives, by using a standard form as shown in appendix 3.3. In addition, an assessment plan must be supplied before the start of the quarter in which courses are scheduled. To ensure transparency, the course information is available through the course catalogue (Osiris) and automatically linked to the digital learning system (Canvas). We have recently been focussing more on providing accurate and up-to-date course information for individual courses. We are working hard to align the large variety of available course information.

Courses are generally executed according to the original planning. However, with relatively small student numbers, the master-apprentice approach may lead to a more flexible approach within courses, naturally always in consultation between students and teachers. Also, the specialised nature of many courses induces a shift from conventional assessment using exams, to more interactive approaches, such as group and/or individual presentations, larger assignments and projects.

As part of their master's programme, students do an internship by performing an assignment at an external organisation, i.e. company or institution, with the primary objective to experience the future professional field and apply knowledge and skills in an actual working environment. Judgement whether the project foreseen is of sufficient quality is done by an academic supervisor from within the Applied Physics domain, who also acts as examiner and as such is responsible for grading of the internship, in consultation with the external supervisor.

3.3 ASSESSMENT OF FINAL PROJECTS

3.3.1 BACHELOR ASSIGNMENT

At the end of their bachelor's programme, students conduct an individual research or design project, either with one of the research groups within the Applied Physics domain, or they may choose to do their final assignment with a company. Prior to their bachelor assignment, students take the Preparation Bachelor Assignment course, where all learning lines meet. The course aims to assist in orientation on possibilities after obtaining the bachelor's degree. Topics include academic writing, effective presentation, personality awareness, scientific integrity, meeting alumni, and orientation on options for further education. As part of this course, students do a literature study and write a research proposal.

In 2012, the bachelor assignment was increased from 10 EC to 15 EC. Until 2015, students were encouraged to do the assignment in couples, with the objective to develop collaboration skills. With the implementation of collaborative projects in TOM and to allow for individual assessment, students have conducted the bachelor assignment individually since 2015. As of 2018, we also register grades for Applied Mathematics/Applied Physics double degree students separately, in consultation with our Applied Mathematics colleagues.

Grading of the assignment is based on performance, a report and an oral presentation, including questioning. The graduation committee consists of at least two members: (i) the chair (generally a scientific staff member), who is responsible for the supervision and (ii) an external reference member, from another group within the Applied Physics domain. A daily supervisor can be added to the committee. The bachelor assignment is assessed with two partial grades, one for general aspects and one for physical aspects, combined into one final grade. To guarantee reliability, consistency and transparency, a standard assessment form is used (appendix 3.4) to substantiate the grade on various criteria. The form is completed by the graduation committee and feedback is shared with the student. Students must scan the final version of their report for plagiarism and submit a similarity report.

From the academic year 2012-2013 until 2019-2020, a total of 297 students graduated; their results are summarised in figure 3.1. In the left panel, the overall grade distribution is shown; the average amounts to 8.1. In the right panel, the grade distribution in the period 2015-2020 is shown, including the distribution of the partial grades. Average grades for general and physical aspects amount to 8.1 and 8.0 respectively.

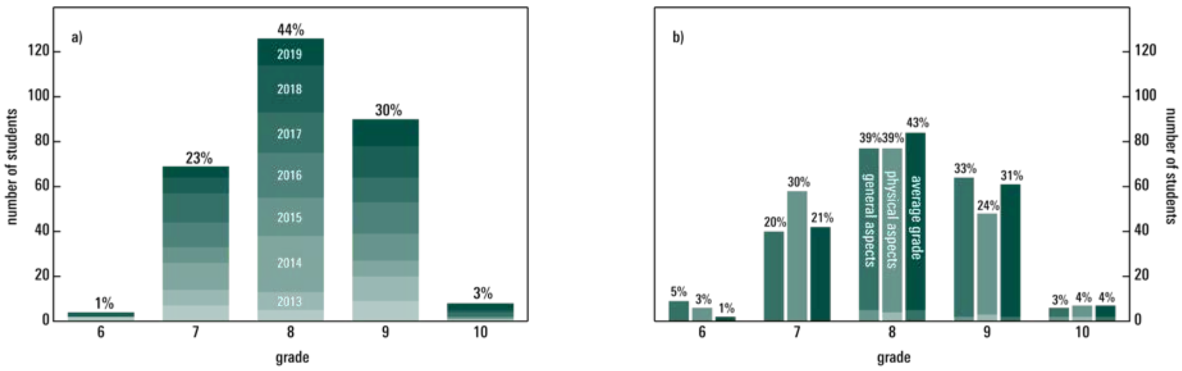


Figure 3.1 *(a) Bachelor assignment grade distribution for 297 students in the period 2012-2019; colours represent different years. (b) Grade distribution for 196 students (including 9 AM/AP double degree students; lighter shade at the bottom of the bars), for both partial grades and the overall grade.*

3.3.2 MASTER ASSIGNMENT

At the end of their master's programme, students perform an individual master assignment. Historically, the master assignment encompassed 50 EC, corresponding to 9 months of work in one of the research chairs in Applied Physics. As outlined in the previous chapter, the master assignment was reduced to 40 EC with the curriculum revision in 2018, equivalent to approximately 7 months of work. Simultaneously, we also started emphasising the option to pursue the master assignment at a company. At the same time, we have seen an increasing interest in double degree assignments over the past years, which we now register separately; since 2017 in collaboration with Nanotechnology, and since 2019 for Applied Mathematics and Biomedical Engineering.

The master assignment is assessed by a graduation committee consisting of at least three members with a PhD degree. The chairman is the professor of the Applied Physics chair where the assignment is done, and the external reference member is from a different Applied Physics group. If the assignment is carried out in a research group outside the Applied Physics discipline, the external reference member should also be a professor. For assignments carried out externally (with a company) at least two independent Applied Physics committee members must be involved. The precise requirements are described in the Rules of the Board of Examiners.

The master assignment is assessed with two grades (one for general aspects, and one for physical aspects) based on the work done by the student, a written report, an oral presentation and discussion afterwards. To guarantee reliability, consistency and transparency, a standard assessment form is used (appendix 3.5) to substantiate the grade on various criteria. The form is completed by the graduation committee after the presentation and feedback is shared with the student. Students must scan the final version of their report for plagiarism and submit a similarity report. The distribution of grades is summarised in figure 3.2. The average grades for general and physical aspects amount to 8.2 and 8.0, respectively.

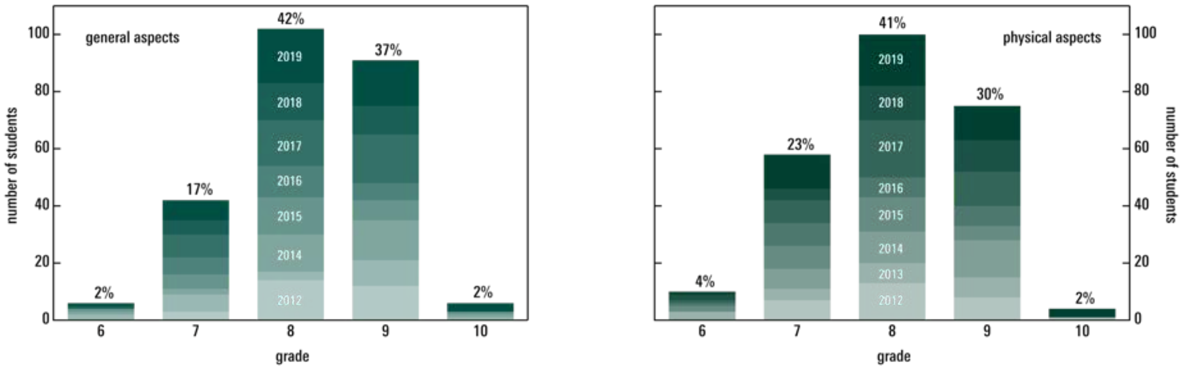


Figure 3.2 *Distribution of master assignment grades for 247 students in the academic years 2012-2013 until 2019-2020, split into general aspects (left) and physical aspects (right).*

3.4 REFLECTION

In this chapter we have outlined our assessment policy, activities and above all final assignments in bachelor and master. As mentioned at the end of chapter 2, the past year has been a challenge for many. This certainly also holds for assessment. With all restriction due to COVID-19, many examinations have been changed from 'on campus' meetings to remote online exams. More recently, the less strict limitations have enabled more on-campus exams, but a proportion of the exams still take place online. In appendix C we outline the implications of the COVID-19 crisis, also in relation to assessment.

The scores from the last four rounds of the National Student Survey (NSE 2015-2019) on testing and assessment are summarised in table 3.3. Appreciation in both the bachelor's and the master's is consistently (very) high, indicating that student value the transparency, validity and reliability of assessment.

Table 3.3 *Student appreciation (on a scale of 1-5) on 'Examinations and Assessment', derived from the NSE (2015-2019).*

Student appreciation (on a scale 1-5)	Bachelor					Master				
	2019	2018	2017	2016	2015	2019	2018	2017	2016	2015
Transparency of the assessment criteria	4.21	4.19	3.99	4.08	4.07	4.33	4.11	4.24	3.97	4.24
Suitability of assessment to the content	4.23	4.31	4.19	4.14	3.96	4.30	4.15	4.33	4.16	4.26
Quality of examination on knowledge	4.31	4.26	4.19	4.18	4.27	4.30	4.15	4.28	4.13	4.21
Quality of practical examination	4.18	4.21	4.12	4.07	4.00	4.15	3.87	4.04	4.00	4.03
Overall score	**4.23**	**4.24**	**4.12**	**4.12**	**4.06**	**4.27**	**4.07**	**4.23**	**4.06**	**4.18**

4. ACHIEVED LEARNING OUTCOMES (STANDARD 4)

In this chapter we elaborate on the achieved learning outcomes. We analyse whether the efforts put towards defining the intended learning outcomes (standard 1), planning for and implementing effective teaching in a well-organised learning environment (standard 2) and qualified assessment (standard 3) lead to the desired learning outcomes. Our evaluation of the achieved learning outcomes is based on the level of our graduates, their career choice, the perspective of our alumni, and the perspective of professionals in the field. We end with a conclusion, including a reflection on the student chapter (see page 12).

4.1 GRADUATES

4.1.1 BACHELOR GRADUATES

The achieved academic level of our bachelor students is reflected, amongst others, in the bachelor assignments. Students perform an individual scientific research project, in which all developed competences are combined. The assignment is generally done in one of the Applied Physics chairs with state-of-the-art experimental and/or theoretical methods, with the aim to provide an innovative contribution to ongoing research. On several occasions this has led to students being co-author on a scientific paper. Students have a wide choice in topics, and since we encourage them to make the most of their project, there is a strong intrinsic motivation. As a result, the grades for the bachelor assignment are generally one point higher than the average for all courses. Details on the grade distribution of the final assignments were presented in the previous chapter (figure 3.1); a list of titles and where the assignments were done in the past few years is provided in the supplemental material.

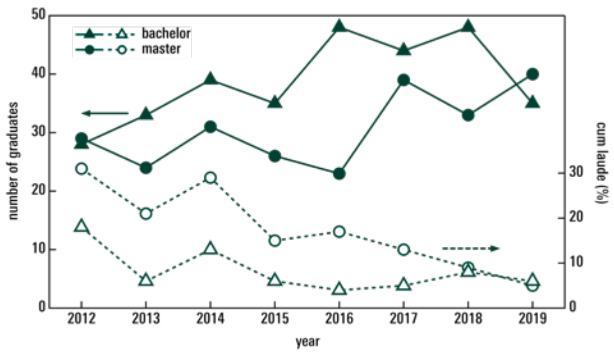


Figure 4.1 *Number of bachelor and master graduates (filled triangles/circles, solid lines; related to the left axis) and 'cum laude' percentage (open triangles/circles, dashed lines; related to the right axis).*

The total number of graduates in the period 2012-2019 is shown in figure 4.1 (triangles represent bachelor). Included is the percentage of students who obtain their degree 'cum laude'. With the introduction of the Twente Education Model (TOM) in the bachelor's, the 'cum laude' percentage has decreased to values between 5-10%. This does not reflect a lower level of our graduates, but much more the effort we have put into tuning the 'cum laude' criteria[18] with the implementation of the new curriculum in 2013.

[18] Bachelor's degrees with a designation 'cum laude' can be awarded when (i) the average grade for the bachelor assignment is 9.0 or higher, (ii) the average of all grades is 8.0 or higher, (iii) all courses are graded with a 7.0 or higher, with the exception of one course at most, and (iv) the total study time does not exceed 3 years.

Furthermore, the achieved level can be derived from the performance of our bachelor students after graduation, and more specifically their choice for a subsequent master's. Nearly all Applied Physics graduates continue with a master's programme at the University of Twente or elsewhere, in which they do well. An overview of destinations is given in table 4.1. The majority of the Applied Physics bachelor graduates, on average 70%, continues with our master's programme. Several students transfer to a related master's at the University of Twente, and a small percentage, varying from 5 to 20%, leaves the University of Twente to start a master's programme elsewhere.

The numbers in table 4.1 are higher than the numbers in figure 4.1. This is due to students who combine two master's programmes. We encourage excellent students to pursue their individual ambitions and talent. On average, every year 2-4 students take up the challenge of a double degree. This number seems to increase slightly. Combinations are very diverse, ranging from Applied Physics combined with Applied Mathematics, Biomedical Engineering, Education and Communication in Exact Sciences, and very recently with Theoretical Physics at Utrecht University.

Table 4.1 *Overview of the destination of Applied Physics bachelor graduates.*

Destination of BSc graduates		2012	2013	2014	2015	2016	2017	2018	2019	overall
UT-TNW	AP	21	20	35	30	39	28	36	23	70%
	NT	-	-	1	1	-	-	2	1	1.5%
	BME	-	-	-	-	1	2	-	1	1.2%
	CSE	-	-	-	-	-	-	1	-	0.3%
UT-EEMCS	AM	-	1	-	1	4	4	1	2	3.9%
	EE	1	-	-	-	-	-	-	-	0.3%
	CS	-	-	-	-	1	3	-	-	1.2%
UT-BMS	ECB	-	1	-	-	2	3	2	-	2.4%
	PSTS	1	1	-	-	-	1	-	-	0.9%
	IEM	-	1	-	-	-	1	-	-	0.6%
UT-ET	SET	-	2	-	1	-	1	-	-	1.2%
	ME	1	-	-	-	1	-	1	-	0.9%
other at UT		1	1	1	-	4	1	1	1	3.0%
left UT		4	7	2	4	4	5	7	8	12%
Total		29	34	39	37	56	49	51	36	100%

As outlined in the Introduction, and more specifically in table 0.1, student appreciation as derived from the National Student Survey (NSE) is very high. For example, in 2019 the bachelor's programme scores a 4.6 (out of 5) on general satisfaction, well above the national average of 4.2. Furthermore, the scores for Applied Physics exceed the national average in all 17 categories, with a 4.8 for ambiance, a 4.2 for general skills and a 4.4 for academic skills. A complete overview of the NSE results can be found in the supplemental material. Furthermore, we conduct an annual exit survey among the bachelor graduates of that year. Results are excellent; scores of the last 4 years (2016/2017 until 2019/2020) amount to 8.1, 8.7, 8.5 and 8.8 (out of 10). On most aspects scores are high, with some room for improvement specifically on design skills and ethical aspects.

4.1.2 MASTER GRADUATES

The academic level of our master students is demonstrated by their course grades, but even more specifically by the performance during their internship and the master assignment. A list of titles of final assignments and where they were performed in recent years is provided in the supplemental material. Learning objectives of the master assignment correspond with the learning outcomes of the master's programme itself. Domain-specific knowledge and skills, as well as the personal performance are assessed during the evaluation of the project. As there is a large flexibility and many ways to tailor their personal programme, students generally have a strong intrinsic motivation towards all aspects of the programme. Also, the close link with our scientists contributes to this. Grades for the master assignment were presented in the previous chapter (figure 3.2).

The previous review panel concluded that the number of students graduating 'cum laude' was very high, and suggested to analyse the cause and take action to reduce the 'cum laude' percentage. After a thorough evaluation and discussion with teachers and staff, the criteria[19] were revised in 2017. In figure 4.1 the number of graduates is shown (circles represent master), together with the percentage of 'cum laude' degrees. The percentage declined from well above 20% in the period 2013-2015 to a value between 5-10% in recent years.

Figure 4.2 *Locations where Applied Physics students (in total 225 between 2013 and 2020) performed their internship, specified (a) per institution, (b) in The Netherlands or abroad, and (c) when abroad where in the world.*

In their second year, Applied Physics master students do an internship, to experience future employment options. In figure 4.2 the various choices of students for internship locations are summarised. Approximately 35% of the students choose to join a company, most often in The Netherlands; 65% of the students travel to many destinations across the globe, to join a research group at a university or a research institute abroad.

According to the NSE of 2019, students highly appreciate Applied Physics; the master's programme scores a 4.5 (out of 5) on general satisfaction, markedly higher than the national average of 4.3. Applied Physics scores better than the national average on all of the 17 categories, with a score of 4.4 for practical skills, a 4.2 for general skills, a 4.3 on pursuit of excellence and a 3.7 on preparation for a professional career (see also table 2.7). A complete overview of the NSE results can be found in the supplemental material.

4.2 ALUMNI

As indicated, almost of the Applied Physics bachelor graduates continue with a master's programme. As such, here we only focus on the alumni of the Master's programme in Applied Physics. For most alumni who graduated between 2013 and 2020 (220 in total) we have information on their first job. From figure 4.3 it follows that 45% continue to pursue a PhD degree, 49% start working in a company, and for 6% their first job is unknown. Most alumni stay in the Netherlands, 18% move to another country.

The National Alumni Survey (NAE) is conducted annually, but unfortunately the response rate to the NAE among Applied Physics students is low. To collect more reliable information from our alumni about the programme, an online survey was held at the end of 2020 amongst graduates from the last 10 years. In total, we received 71 responses. In general, our alumni are very positive about the programme, as shown by the highlights in table 4.2. Some more quantitative results are summarised in appendix 4.1, and the full report can be found in the supplemental material.

[19] Master's degrees with a designation 'cum laude' can be awarded when (i) the average grade for the master assignment is 9.0 or higher, (ii) the average of all grades is 8.5 or higher, (iii) no resits are taken into account, and (iv) the total study time does not exceed 2 years, i.e. nominal.

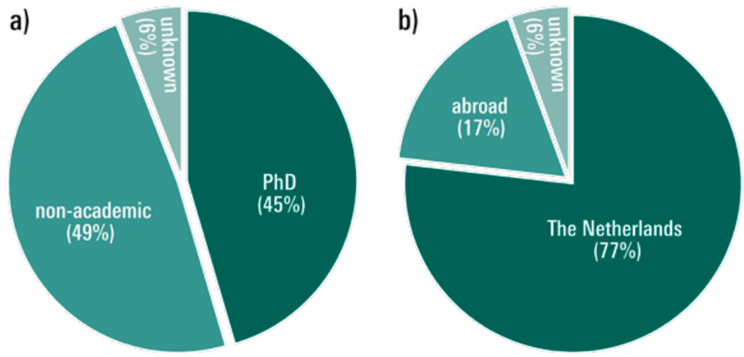


Figure 4.3 *First job of 220 Applied Physics alumni who graduated in the period 2013-2020, distinguishing between (a) academic or corporate, and (b) in The Netherlands or abroad.*

From our survey we derive that over 75% of our alumni consider the master's programme a good starting point for entering the job market and well over 90% indicate that the master's is a good starting point for further professional development (appendix 4.1). Finding a job is relatively easy. Almost 60% found a job even before their graduation date, and all alumni found a job within 4 months after graduation. Moreover, the survey reveals that about 70% of our graduates work in an applied physics-related field, and little over 70% indicate that they work at master or PhD-level. Jobs held by Applied Physics alumni include engineer, sales manager or consultant, data scientist, project manager or a position in research and development, either in academia or within a company or institute.

Table 4.2 *Highlights from the alumni questionnaire – general opinion about the programme*

100%	satisfied or very satisfied with the Applied Physics programme in general.
94%	satisfied or very satisfied about the degree to which science and engineering are balanced in the programme.
98%	satisfied or very satisfied about the content of the programme.
88%	satisfied or very satisfied about the acquired general skills (e.g. critical attitude, problem solving, argumentation skills, communication skills and collaboration skills) within the programme.
97%	satisfied or very satisfied about the acquired academic skills (e.g. analytical thinking, critical assessment of scientific work, writing scientific papers, and conducting research) within the programme.
84%	would choose for Applied Physics at the University of Twente again.

Strong points of the programme according to our alumni are (i) the accessibility and the expertise of our lecturers, (ii) the organisation of the programme, (iii) the academic counselling and guidance provided by the programme, (iv) the programme's quality assurance system, (v) the access to high level research groups and (vi) the general atmosphere. Points of improvement that were mentioned were (i) more projects from or with a direct link to industry, (ii) more focus on job market preparation, in particular on careers outside academia/research, (iii) more focus on soft skills, and (iv) more focus on acquiring design skills.

4.3 PROFESSIONAL FIELD

Contact with the professional field is generally via our alumni, but also through industrial partners of the various research chairs. As indicated in figure 4.3, many alumni continue in a PhD position, mostly at the University of Twente. Obviously, we are in close contact with the research groups where students continue their academic career. The fact that chairs often select candidates who already work in their group on their final assignment, demonstrates that they appreciate the education level of our graduates.

Alumni outside academia, working in education, corporate enterprises or government institutions also provide valuable information. There are many chances to meet and exchange experiences and suggestions. For example, alumni are invited to the annual symposium organised by study association Arago. Also, every 5 years Arago's anniversary is the ideal opportunity to host alumni, and show how 'their' Applied Physics programme is doing. In 2019 we celebrated 50 years of Applied Physics in Twente by means of a symposium with many opportunities for interaction between students, staff and alumni.

To increase visibility of the many job options, we regularly invite alumni or colleagues from the field to share their experience about their work, their career path or any other specific contribution to a course or symposium. These meetings, and especially the associated informal contact, provide ideal occasions to exchange ideas and for us to hear what is happening in the professional field. In this respect, internship supervisors outside academia can also provide valuable feedback on what they consider important in our programme. To stay in close contact with these supervisors, we aim to have UT supervisors involved who are closely linked to the programme staff; often, the programme director fulfils that role. As a simple example of input from industry, we consistently picked up that Applied Physics students missed programming skills specifically in Python. Consequently, we switched from MATLAB to Python as the primary programming language in the bachelor's programme in 2018.

4.4 REFLECTION

Based on the performance of our graduates and the perspective of the alumni, we conclude that both the Bachelor's and Master's in Applied Physics meet the learning outcomes and also that our learning outcomes are in line with the requirements of the professional field.

4.4.1 STUDENT CHAPTER

We strongly value the opinion of our students and are proud of their role in the Applied Physics programme. The student members of the programme committee wrote the student chapter (page 12) based on their experiences and analysis of the programme, and feedback from many of their peers. We are very glad to see that they cherish the same core values in education as we do.

The students elaborate on the pleasant working environment, attributing it to the small scale of the programme. As staff we feel strongly committed to being involved in all aspects of the programme, and in that collaborate closely with study association Arago. This leads to a unique atmosphere, providing a solid foundation for personal development in a familiar, comforting and safe environment. Let's not forget, studying should be fun! This connects with our continuous efforts to jointly search for ways to improve. Quality assurance is only possible if students experience a low threshold for giving their opinion. In turn, we listen, discuss, and see what can or cannot be done.

The student-focused approach within Applied Physics is mentioned. With each student we strive to make the most of their individual learning process. Our study advisers meet and discuss with every student, and search for flexible solutions that fit their capabilities, limitations, ambitions and personal development goals. Students who struggle and experience a high workload or other hinderances, will benefit from drawing up a personalised planning. Mental health is an important part of feeling comfortable; judging from the student's perspective, there is room for improvement at programme and university level. Mental health can be higher on the agenda, but also to highlight both sides: Some pressure and a moderate stress level now and then lead to a better performance; but if this becomes problematic, we must provide assistance and students should know where to turn to.

With respect to personalised study planning, it is reassuring that students recognise the flexibility we aim for. Apparently, in the bachelor's programme this is sufficiently visible. We will explore options to improve in the master's. Finally, the relevance of the programme seems sufficiently clear, but there should be more emphasis on job orientation and providing students with enough information to make informed decisions. This includes more emphasis on the possibility to perform final assignments with a company.

OUTLOOK AND AMBITION

As described in the Introduction, global society is rapidly changing. Our students and alumni are faced with complex challenges, which become increasingly interdisciplinary and of an international nature. This requires flexibility from our students, teachers and alumni to adapt to these changes. As programme staff we are also obliged to continuously monitor our education and respond when needed. In the previous chapters, it was outlined that for continuous development we rely heavily on input from teachers, students and alumni, through surveys and evaluation meetings. In the end, it is our objective to optimise teaching activities, support and facilities to ultimately provide the best learning environment for our students. In doing so, we stay true to our motto '**Together we educate; partners in teaching and learning!**'[2]

Based on the self-assessment presented in this report, strengths of the Applied Physics programme at the University of Twente were identified. We summarise them in appendix B, together with opportunities for further development. Below we highlight some of our plans for the near future and with that our ambition to guarantee a robust, student-focused educational programme.

Continuous fine tuning of the curriculum, the programme, teaching activities and facilities is essential to ensure optimal learning conditions for our students, effectively our future colleagues. This includes making sure that information to students and staff is accurate and reliable, and readily available through our website, the course catalogue and information meetings. This certainly also holds for marketing and outreach, including the open days and student-for-a-day activities. We feel committed to providing prospective students with accurate and truthful information on what it is like to study physics in Twente, enabling them to make informed decisions about the first steps in their academic career.

Besides the existing evaluations on module and course level in the bachelor's, we intend to initiate a curriculum evaluation with students who have reached the end of their bachelor studies. If successful and informative, we envisage repeating this annually. This will allow us to assess the programme on a level that exceeds that of the educational units. As described in chapter 1, the intended learning outcomes (ILOs) were recently reformulated to better match our ambitions with respect to development of our students. In line with all quality assurance activities, the curriculum evaluation will also be aimed at identifying on which aspect we are doing well, and especially where we can improve.

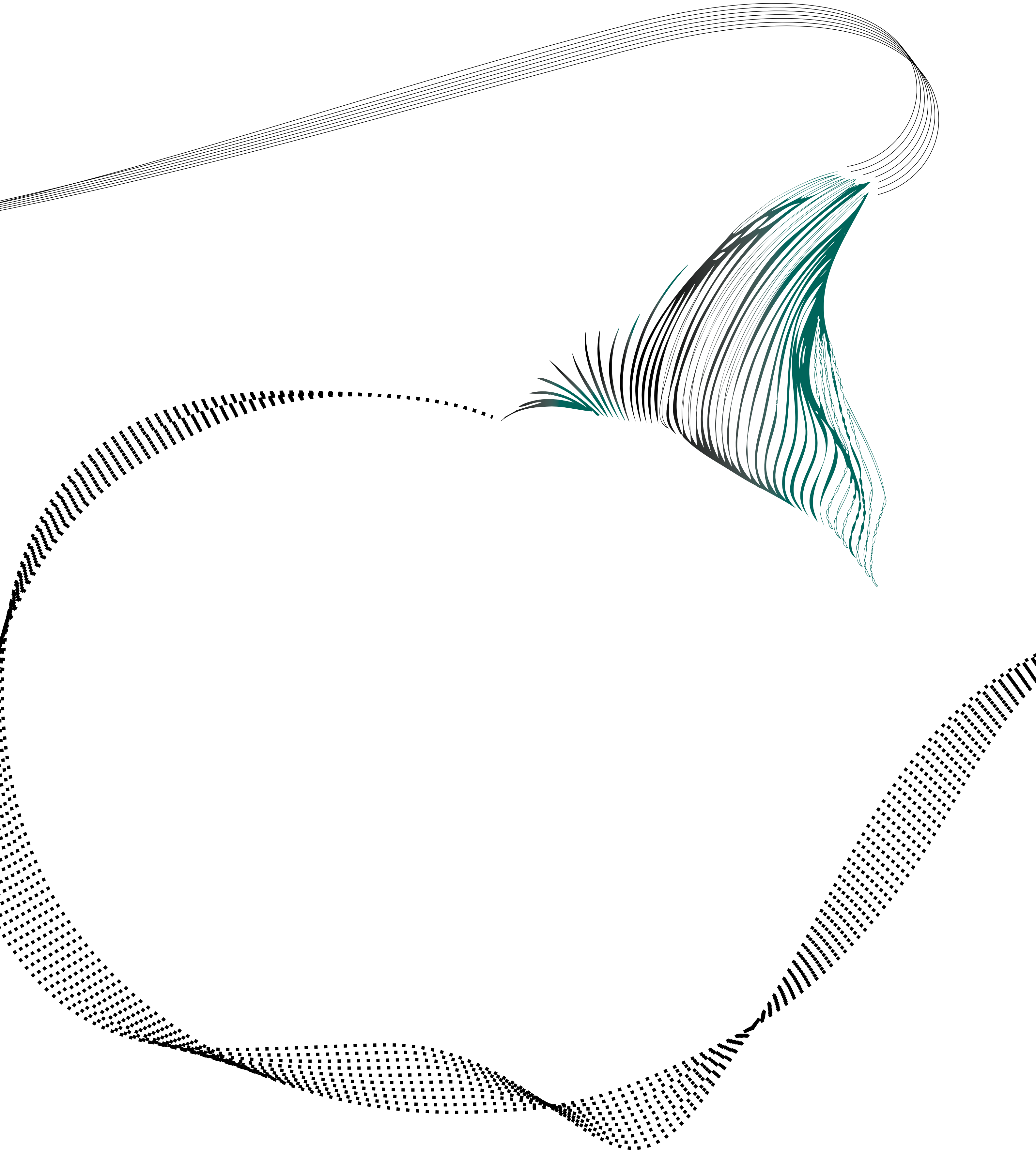
Likewise, following the change of the master curriculum in 2018, the content and objectives of the individual courses within the various research cluster have been reported to show overlap and misalignment in some cases. Similar to the learning lines implemented in the bachelor's, we intend to further align the many specialisation options for students to ensure comparable development in terms of general academic competences. Ideally, we envisage to match the specialisations in the master's programme with the focal points of the research clusters.

To support the programme staff in curriculum developments, a curriculum committee was recently (re)initiated. Within this platform, colleagues from all domains within the discipline discuss the present state of both the bachelor and master curricula and possibilities for the future. We specifically choose to also include new colleagues, who recently started in the various research clusters, as they have many interesting new ideas. The curriculum committee will work besides existing committees. As such, it is important to clarify the responsibilities of the various committees. The curriculum committee is in charge of monitoring and improving the **content** of the programme, i.e. subjects, learning lines and cohesion.

Concerns about student well-being were already mentioned in the student chapter. As programme staff we are also well aware of the increasing stress experienced by many of our students. Various causes have been identified, including the binding study advice (BSA) in the first year, financial limitations, societal pressure to do well, study in nominal time and, simultaneously, get the most from their time as a student in academia. We are convinced that a certain amount of stress, or better discomfort, is beneficial to the learning process.

We refer to the top sports mentality: Only when working at the limits of their abilities and venturing beyond them, will students make significant steps in their personal development. But at the same time, they must know who to turn to and what possibilities for support are available through study advisers and also within the university. And it helps when students frequently discuss this among themselves, but also with teachers and staff. Especially in the last year, the severe restrictions due to the COVID-19 crisis have not made student life easier. For more information on how we are dealing with these special circumstances, we refer to appendix C.

Finally, a recent initiative developed within the Applied Physics programme is starting to resonate within the University of Twente: the so-called multidisciplinary master specialisations. By combining courses of several (disciplinary) degree programmes in a smart way, we design specialisation programmes that more specifically focus on multidisciplinary research focal points. Where education is traditionally organised in line with classical disciplines, certainly within physics, these specialisations aim at a stronger link with research to create a community of young academics sharing the same interest as their more experienced tutors. This unique approach not only provides opportunities for a new marketing strategy to attract students from all over the world, but also provides a solid base for collaboration with industry. The latter ties in perfectly with the vision of the University of Twente as formulated in Shaping 2030 and the resulting master vision. Specific programmes presently being developed are in 'Materials Science and Engineering', a collaboration between Chemical Science and Technology, Mechanical Engineering and Applied Physics, and 'Fluid Dynamics', bringing together research clusters within Applied Physics and Mechanical Engineering.



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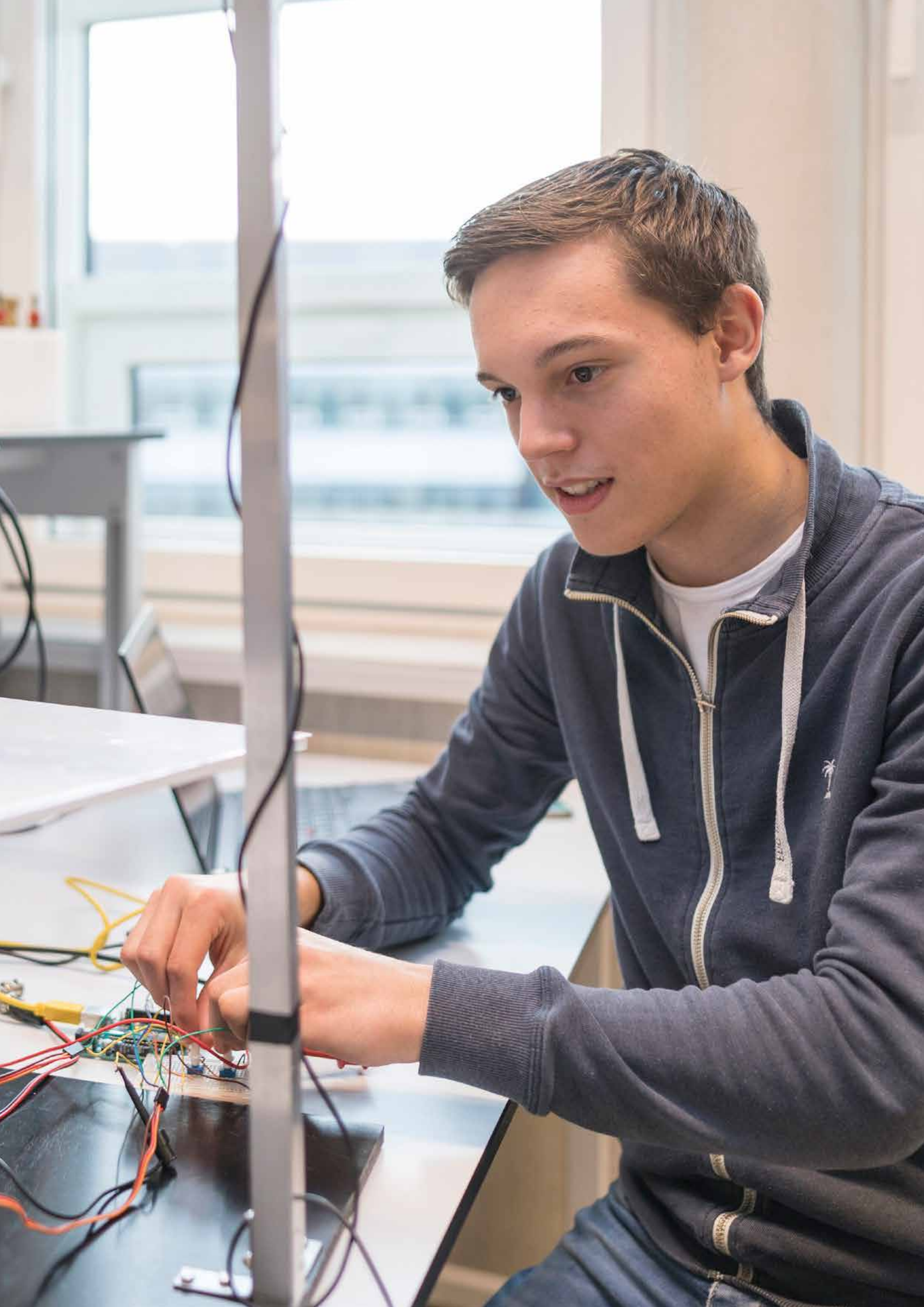


APPENDIX A. RECOMMENDATIONS, FOLLOWING FROM THE PREVIOUS EVALUATION IN 2014

In 2014 the external evaluation panel formulated several recommendations, which were included in the final report. Below we list all recommendations and describe how improvements have been implemented. The first two recommendations pertain to the bachelor, followed by two issues specifically for the master. Other recommendations are relevant for both the bachelor's and the master's programme.

Recommendation: 'The assessment committee urges the programme management to reflect on whether all learning outcomes are realistic and match the programme in its current form' (BSc)

Action taken: Following the previous evaluation and with the implementation of the Twente Education Model (TOM), the curriculum has evolved to comply with all learning outcomes. Nevertheless, over the past years discussions have led to a redefinition of the intended learning outcomes. The modified learning outcomes are presented in chapter 1, and related to the present curricula in chapter 2, both for the bachelor's and the master's programme.

Recommendation: 'Completion rates of the bachelor's programme are low, mainly because of a delay during the third year. The committee urges the programme management to implement appropriate solutions to reduce this delay.' (BSc)

Action taken: We agree that the number of students completing the bachelor's programme in three years is relatively low. As outlined in chapter 2, the completion rate in four years is considerably higher. Several reasons can be identified. One cause originates from the fact that many of our students are active either within or outside the Applied Physics programme. For example, students participate in committees or become a board member of study association Arago, or with a more central association or organisation, such as a sport association or the Kick-In committee. Also, quite a number students participate in one of the multidisciplinary student teams, such as the Solar Team, the Solar Boat, the Aerobotic Tech Team or the Green Team. Although we strongly encourage our students to be active, these activities generally lead to a delay of a year or more, but substantially add to their development as academic professionals. Within the Applied Physics programme we enable students to fill part of the minor by writing a report to reflect on their activities within these multidisciplinary teams.

Another reason for substantial delay has been the original implementation of TOM, making it difficult to take only parts of modules. With Applied Physics we have always emphasised the individual development of each student, and with that a flexible approach while keeping an eye on what is best for everyone's personal development. To provide for such flexibility several solutions were sought, such as (i) using the minor to make a tailored programme comprising courses or module parts in a specific direction, (ii) offering the compulsory Preparation Bachelor Assignment course twice a year, enabling students to start their bachelor assignment at different times in the year.

Finally, in the past students took considerably longer to finish their bachelor assignments than the envisaged ten weeks. Over the last two to three years we have noticed a natural incentive (also enforced by the general opinion in society) to aim for a nominal study duration. In that respect, as part of Preparation Bachelor Assignment we help students to make a more realistic planning for their final assignment and motivate them to take control and have frequent discussions with their supervisors. In addition, we discuss with supervisors to not prolong the assignments much longer than nominal time.

Recommendation: 'In view of their future practicing of a profession, it is important that students learn to work with time constraints. The traditionally large freedom which Dutch students had and partly still have, can easily lead to the neglect of this aspect in study programmes. Time management should be an explicit part of elements of the programme, in particular for a research project or an internship.' (MSc)

Action taken: Using the momentum arising from changes in the bachelor's, we have been able to establish a similar culture change in the master's programme, with students being more focussed on a nominal study time. Apart from external influences such as general opinion in society, discussions with students and staff leading to the master curriculum change in 2018 have contributed to this. The reduction of the master assignment from 50 EC to 40 EC, effectively decreasing time spent from 9 to 7 months, together with the new option to extend the internship from 20 EC to 30 EC, led to awareness of time constraints, both for students and staff. Additionally, the fact that most of our present master students completed their bachelor's programme within TOM, combined with an increased emphasis on effective planning in the Preparation Bachelor Assignment course, has led to more focus on feasibility of the study.

Recommendation: 'The programme could position itself better internationally by highlighting its unique character in comparison to similar programmes elsewhere – in The Netherlands and abroad.' (MSc)

Action taken: Although the recommendation was only formulated for the master, we have increased our efforts over the past years to position both the bachelor's and the master's programme more specifically. During the Open Days of the University of Twente, for instance, we more clearly highlight the international character of our programme. Also, the unique features are more explicitly mentioned, focusing more on the educational model in the bachelor's, and in the master's more specifically on the leading international role of our research.

With an increased global focus on internationalisation, our students are also more focussed on the programme's relevance in this respect. The fact that they are educated by staff of many different nationalities contributes significantly. The same pertains to bachelor and master assignments, which are often performed in research groups, which without exception are very diverse communities comprising many different nationalities.

Several years ago, we introduced so-called general module introductions by the programme director during the kick-off for each bachelor module. But more importantly, we strongly focus on the activities of teachers outside the lecture halls. What are their research activities? Who are the big names in their field of expertise? Whenever possible, these presentations include references to recent news articles in the media to highlight achievements of our colleagues.

Recommendation: 'The programme depends heavily on the study association Arago for job orientation outside research. The committee strongly suggests that the programme management secures a more prominent place for job orientation activities within the programme.' (BSc + MSc)

Action taken: We agree with the conclusion that job orientation also lies with Arago; we truly value that. Lunch lectures in which companies introduce themselves, as well as general excursions are very relevant activities for our students. Study association Arago relies on sponsoring related to these activities. In chapter 2, we describe how we have intensified our collaboration with Arago in the last years, also on the aspect of job orientation and how we have teamed up to organise job orientation activities jointly to secure a more prominent place in the programme.

Recommendation: 'Less attention seems to be paid to the didactic concept underpinning the programme: the use of problem- and project-based learning as the most important teaching method. The didactic concept is not very transparent and requires further elaboration.' (BSc + MSc)

Action taken: With the introduction of TOM in 2013, the didactic concept in the bachelor's has been subject of quite some debate. Often the discussion is between those supporting the more classical approach of lectures, tutorials and written exams, and others interested in exploring other teaching methods and exploring novel ways to enhance learning. In chapter 2 we present a more elaborate description of the didactical concept, as we have implemented it over the past few years.

In the master's, the focus was and remains on more self-directed autonomous learning, by giving students more freedom to develop their own learning path. The master-apprentice relation is very important, and most prominent in the execution of the master assignment. Additionally, within courses a shift is noticed away from the more classical forms of education, to more project-oriented ways of working, giving students more responsibility and teachers exploring alternative forms of teaching and assessment.

Recommendation: 'The implementation of TOM has made great demands on the lecturers. The committee concludes that the university and faculty have not anticipated this and should have provided the necessary support to cope with this extra workload. The high workload has also resulted in the fact that a significant percentage of staff has not yet obtained a basic teaching qualification (BKO).' (BSc + MSc)

Action taken: The implementation of TOM has indeed been an intensive operation, requiring a lot in time and energy of our staff and teachers. With continuous monitoring, optimisation and implementation of changes, this has continued for quite some time. After several years, we reached a stationary situation enabling us to assess what is needed in terms of extra support in staff and facilities. Over the past years, we have been able to attract two teachers who are employed within the programme to take care of important learning lines related to programming, experimental and project skills.

Furthermore, over the past years we have seen several new young staff coming in primarily on tenure track positions. Together with stricter requirements on obtaining the UTQ (BKO), the recent initiative on 'Recognising and Rewarding of Diversity in Academic Profiles' has led to more focus on the importance of teaching. Moreover, we notice that young incoming staff are eager to develop in and contribute to education within our Applied Physics programme. With this, we hope that the workload will become manageable and we anticipate that the number of UTQ-qualified colleagues will increase.

Recommendation: 'The committee also finds it very important that the implementation of TOM is supported with the necessary facilities: administrative support for the lecturers and adequate teaching facilities for problem- and project-based learning.' (BSc + MSc)

Action taken: In addition to what is written above, the faculty board has allowed us to extend our programme staff. Presently, we have the luxury of two study advisers, both with an academic background, and a full-time programme coordinator who takes care of education-related administrative support. Moreover, a dedicated and highly involved colleague with Student Affairs and Logistics (CES) facilitates the central administration for the board of examiners and the programme committee. The faculty's Educational Support Office provides support related quality control, and more general educational policy.

In addition, support for experimental and project work is provided by Student Laboratories Twente (SLT). Dedicated staff members are involved in keeping the lab facilities in top-notch condition, but also help students and staff with a large variety of content and organisational related issues of the different projects. Finally, the Centre of Expertise in Learning and Teaching (CELT) supports staff in designing, implementing and conducting all sorts of educational activities, by providing training programmes and/or workshops and coaching of individuals or groups.

Recommendation: 'The Programme Committee, which can play an important role in the process of quality assurance, could have been better informed about the implementation of TOM. The committee stresses the importance of a well-informed, pro-active Programme Committee. This Committee can help identify problems before they occur (not only at a course level, but also at the level of the programme as a whole) and to solve these problems.' (BSc + MSc)

Action taken: Both the programme committee and the programme management take considerably more effort to keep each other informed on all aspects of the programme. Any envisaged changes within the programme are sent to the programme committee for advice. Recent examples are curriculum changes, course contents, but also discussions on language and planning of resits for courses. Alternatively, the committee stays in contact with the management on relevant topics, such as for example the quality agreements and implications for the programme and its organisation. Together we strongly value the cooperation to constantly improve. This is also concluded from the student paragraph, which was written by the student delegation of the programme committee.

Recommendation: 'The committee stresses the importance of evaluating not just individual courses, but the programme as a whole. For this and other purposes, it would be desirable if the programme kept closer ties with its graduates.' (BSc + MSc)

Action taken: Although we constantly have an eye for improvement of the programme as a whole, there have up to now not been any specific curriculum evaluations. We intend to do this at the end of the academic year 2020-2021. Parallel to that, we are initiating a new curriculum committee, with a strong link to the programme committee. Members of the committee constitute a representative cross-section of the Applied Physics discipline at the University of Twente, including both young staff members who recently joined us, as well as more experienced colleagues. We have also discussed to include one or several alumni, but are reluctant to formalise this owing to expected issues in planning meetings.

Nevertheless, many changes we have implemented over the past years, have been based on input from students, staff and alumni. Results of the National Student Survey (NSE) as well as the National Alumni Survey (NAE) provide valuable input, together with discussions with our staff, programme committee and board of examiners. Moreover, as outlined above, we have frequent contact with many of our alumni at various occasions. We do not miss out on opportunities to reflect with them on recent or intended changes.

Recommendation: 'The Board of Examiners could adopt a more proactive role. The Board should for example formulate an opinion on the assessment of group work in the bachelor's programme. Also, the Board should decide on its line of approach in matters such as detecting fraud and plagiarism.' (BSc + MSc)

Action taken: The role of the board of examiners has changed over the past years. With the implementation of TOM, a more pro-active monitoring of assessment in modules has been adopted. In the design of TOM modules, the standpoint of the board of examiners was that all module parts should be completed with a satisfactory grade. In the last two years, the board has invited module coordinators during their meetings to comment on assessment plans and testing within their modules. This encompassed not only a look in hindsight of what happened, but also what will be improved in a subsequent addition.

In the discussions with module coordinators, the balance between individual testing and group work receives constant attention. Also, in consultation with the programme management and following the recommendations of the previous review panel, the board recommended to change the bachelor assignment from a group assignment to an individual project. With the introduction of the project learning line, individual assessment of the final project was considered more relevant.

As for detecting fraud, plagiarism and other forms of misconduct, the primary course of approach is to react on reports from teachers and staff. Fortunately, this has only occurred very rarely. As for detecting plagiarism in reports for final assignments, the board of examiners now requires that all work is scanned for plagiarism and a similarity report must be submitted together with the final report. Simultaneously, a discussion rose what is acceptable in terms of overlap in these similarity reports. An analysis was performed on reports collected in two years, which led to two conclusions: (i) in these two years, there were no indications of misconduct, and (ii) defining a specific threshold for similarity percentage is not straightforward.

Finally, the board of examiners has certainly taken on a pro-active role in dealing with the COVID-19 crisis. Numerous discussions have taken place on alternative ways of testing, desirability of proctoring and achieving the learning objectives of courses. In all cases, decisions and/or advice has been formulated which strike a balance between meeting the intended learning outcomes of the programme and what is best for the learning process of the student.

Recommendation: 'The percentage of graduates that obtain their diploma with the distinction 'cum laude' is high. The Board of Examiners was unaware of the exact numbers.' (BSc + MSc)

Action taken: The comment was taken seriously and discussed with all stakeholders within the programme. This led to awareness with teachers and supervisors, and the corresponding desire to reduce the percentage markedly. Following a thorough analysis of grades, their distribution of courses and the distribution of final assignment grades over different research groups, the board of examiners decided to tighten the 'cum laude' guidelines for the master. For the bachelor, it was anticipated that with the introduction of the Twente Education Module (TOM), the 'cum laude' percentage would drop anyway. As outlined with standard 4, this has led to a marked decrease of 'cum laude' percentages.

Recommendation: 'The introduction of a new assessment form for the bachelor's research project in September 2013 has led to more clarity on the weighting of the elements the final grade is based on. It would be preferable if a similar form was adopted for the master research project. In addition, the programme management and the Board of Examiners should stress the importance of filling in the forms properly.' (BSc + MSc)

Action taken: Following the positive response on the introduction of assessment forms for the bachelor assignment, a similar form was introduced for the master assignment. A more elaborate supporting information document was appended and sent to all supervisors. The programme management repeatedly stressed the importance of properly filling in the forms, explaining that this contributes to an honest, reliable and consistent assessment of the assignments. In addition, supervisors were motivated to share their feedback with the candidates. We are convinced that most forms are properly filled in nowadays.

APPENDIX B. STRENGTHS AND OPPORTUNITIES

In this appendix, we summarise the strengths and opportunities of the Bachelor's and Master's programmes in Applied Physics at the University of Twente. We list the aspects we are proud of and describe where we see options to further improve. We chose not to present a full SWOT analysis, since weaknesses naturally translate into opportunities for future development.

STRENGTHS

- The objectives of the bachelor's and master's programmes are clearly defined in terms of knowledge, skills and attitude to deliver academic professionals with an Applied Physics profile.
- The teaching staff is qualified, dedicated and committed to contribute optimally to the student's learning experience.
- The SLT-group (student laboratories) provides highly skilled and devoted staff, that actively participate in design, execution and optimization of lab course assignment, projects and remote experiments. Student appreciation for the activities of SLT and especially the staff is high.
- There is a strong focus on student-driven learning, with attention for every individual student and his/her learning process. We strongly value the responsibility students take toward all aspects of their study programme.
- Our two study advisers have a broad academic background (both with a PhD degree). Their professional experience, combined with their academic level and orientation, make them excellent sparring partners for our students, able to help them when needed.
- There is a strong sense of community among students, teachers and staff, providing a unique learning environment.
- Study association Arago is fully embedded within the programme and provides valuable contributions to the academic development of our students.
- The intended learning outcomes are aligned with the domain specific framework of reference.
- Both the bachelor's and master's programmes offer flexibility. Together with excellent student support by study advisers, we strive for the most optimal study planning for every individual student.
- Students actively participate in all aspects of our educational programme. Under supervision of qualified staff members, student assistants play an important role in teaching, design and development of educational activities.
- The majority of Applied Physics bachelor graduates continues with our master's programme, indicating that they value the quality and level of our programmes.
- The board of examiners is well-aware of its role, acts accordingly, but also has an open mind to specific needs of students.
- 'Cum laude' percentages in both the bachelor's and the master's programme are well within the range of 5-10%.
- Clear guidelines for the grading of bachelor and master assignments and the composition of the graduation committee guarantee transparent, reliable and consistent assessment.
- Semi-annual approval of staff members in various roles (graduation committee, internship supervisor) ensures fair assessment and provides clarity to students and staff.
- The Applied Physics programme is an excellent preparation for a position in the professional field, with a sound basis for further professional and personal development.
- Applied Physics alumni easily find a job after graduating, in many different sectors. Most alumni work in the field of (applied) physics and hold positions in which a university master's degree is required.
- Student and alumni appreciation on all aspects of the programme is excellent. Both the Bachelor's and Master's in Applied Physics have been top-rated programmes for many consecutive years.

OPPORTUNITIES

- Currently, we focus on delivering complete and reliable course information to students through the course catalogue, in order to enable students to make informed choices on their study planning and to ensure transparency on content, learning objectives and grading.
- The transition to online education in the past year has revealed the enormous potential of remote teaching and learning, including assessment.
- Some of the teaching that is provided by colleagues from outside the discipline can be better embedded in, integrated with and/or linked to the core curriculum. In addition, occasionally students are disappointed about the content and level of some minors not related to our faculty; more reliable information may provide a solution.
- For various reasons, not (yet) all teachers have been able to complete their UTQ. We see an influx of young colleagues who are eager to develop their educational skills and are focussed on obtaining their UTQ. The focus on recognising and rewarding diversity in academic profiles, especially in education, certainly helps in this respect.
- Alumni are generally well aware of the development they have gone through during their studies. However, this was not immediately obvious while they are studying. By more clearly identifying the learning lines in the curriculum (to students), we aim to enhance the awareness for their own development in terms of general academic competences.
- The master's programme consists of many courses, with scattered content, a strongly varying contribution to the ILOs and flexibility is not always appreciated by all students. A better alignment of the master specialisation courses within the different research clusters will be the focus for the coming one to two years.
- The apparent focus of our education is geared towards a scientific career. Alumni indicate that a stronger link with the professional field outside academia is beneficial for orientation on the many career opportunities. This ties in with the UT ambition as expressed in its vision Shaping 2030, i.e. to more closely (and clearly) link teaching activities to corporate and societal challenges.

APPENDIX C. ADAPTATION TO THE COVID-19 CRISIS

On Friday, March 13, 2020 the quickly spreading COVID-19 virus resulted in a complete closure of all universities, marking the start of a period of great uncertainty, which still persists to this day. It is very likely that the COVID-19 crisis will continue to affect society - and thus academia - for quite some time to come. In this appendix, we briefly describe how we have dealt with the rapidly evolving crisis so far. We do this by providing answers and background information to five specific questions.

1. **How was the education adapted to the changing conditions due to the Corona virus? What measures have been taken?**

The switch to full online education was initiated almost immediately. After the closure of the University of Twente on Friday, March 13, teachers and staff successfully transitioned to remote education within one weekend. On Monday, March 16, the first meetings with students were held online. Overall, the commitment of teachers and staff has been enormous.

The Board of Examiners (BoE) has been considerate and lenient in favour of study progress and student well-being. In an extra meeting on March 16, the BoE agreed to deviate from assessment plans and conduct all exams remotely, either online or via Skype/Teams. Furthermore, it was decided to be flexible with respect to sequential study units (for example, by delaying internships). The possibility to delay experimental bachelor assignments until after summer 2020, and to take master courses instead, the so-called 'zachte knip', has been used by quite a number of students. All these measures were taken to limit study delay as much as possible.

As for lab courses, innovative solutions have been developed. In some cases, experiments were redesigned, or facilities were provided to enable experiments at home or remotely. For the Geometrical Optics course, for example, new experimental assignments were developed, using common household items. By using a simple ruler, a bucket of water and a (smartphone) camera, students had to determine the refractive index of water. For another course, a number of setups that are normally operated from a computer next to the equipment, were redesigned to enable remote operation. These activities inspired one of our teachers to design a course specifically on this topic, entitled 'Remote Control of Experiments', which is now one of the elective courses in the third year of the bachelor's.

2. **Has all or part of the teaching been converted to online teaching? What does that mean for the quality of teaching?**

In the period March-August 2020, all educational activities were converted to remote education. This exceptional situation has confronted us with unprecedented challenges, forcing us to venture away from the more conventional teaching methods, such as lectures and tutorials. In the past year, the teaching staff had to get familiar with all the possibilities and limitations of remote teaching. Overall, the lack of face-to-face interaction has led to an impoverishment of our education, which, in turn, has had a significant impact on the personal development of our students.

As outlined in this report, qualification, socialisation and personification form the pillars of modern higher education and, with that, the development of young academic professionals. We believe that in order to achieve these goals, personal interaction is essential. Qualification in terms of theory can be achieved online and remotely, but skills and attitude can only be fully developed on campus. The aspects of socialisation and personification require a great deal of interaction among students and with teaching staff. This has been hindered considerably, despite all efforts by staff and students and all the technological achievements in terms of ICT tools.

In the period from September-December 2020, we were, fortunately, able to offer our students more on-campus education. Under strict conditions, it was again possible to organise tutorials, lab courses and project work on campus. The physical presence of students on campus allowed us to interact with them and to involve especially our first-year students in our tight-knit Applied Physics community. Unfortunately, with the lockdown and the closure of universities in December, the physical distance between students and university increased again. Luckily, it remains possible to facilitate practical work, such as lab courses and final bachelor and master assignments on campus, and also most exams can be held on site. Students have indicated that they appreciate this very much.

Sadly, we must admit that the overall quality of our education has suffered from the COVID-19 crisis. This is most apparent in activities where students work together on problems, assignments, or projects. And, as mentioned above, especially the personal development of our students in terms of skills and attitude is affected. It is difficult, if not impossible, to educate engineers remotely via a computer screen.

3. How is assessment designed in these circumstances?

As mentioned above, in the period March-September 2020 all assessments were conducted remotely. Most of the exams were so-called open book exams, in which students were allowed to use designated study material. The exams were made available online (through Canvas) at the start of each exam, and students were asked to upload their solutions at the end. Of course, students were given enough time to scan, compile and upload their documents. Some teachers preferred to organise individual oral exams, which proved to be a lot of work, but at the same time allowed for very adequate assessment of the student's level.

Possible fraud has been a frequent topic of discussion, among management and students. Hence, the necessity of proctoring has been debated a lot, primarily in relation to privacy and reliability. It has been and still is our opinion that proctoring is not a good solution. Up to now, we have chosen not to implement it within the Applied Physics programme. Instead, in case of a remote exam, we ask students to copy an integrity statement on their exam paper, in which they declare that it is their work, and the result of their own activities. In grading the remote exams, teachers assessed any possible indications of fraud, and up to now we have not been able to identify any suspicious situations. We have relied on mutual trust between students and staff, and this has so far been appreciated and respected by all.

Generally, student appreciation for the transition to remote assessment has been high. Especially our ambition to keep education on track and to stick to the schedule, also in terms of assessment, was well received. Thanks to the changes in our assessment procedures, we have been able to finish the academic year 2019-2020 on time, with only one exception: A second-year lab course assignment on fluid physics, which could not be done on campus nor remotely. The course had to be postponed, but is currently being caught up. With a flexible attitude of students and staff, this delay has been resolved without compromising quality and level.

As of September 2020, it is possible to conduct most exams on campus, , of course in compliance with the COVID-19 rules. The majority of students and teachers indicate that on-site exams have their preference.

4. How has the programme monitored the effects of these measures on the quality of education, the learning outcomes achieved and what actions resulted?

As for monitoring of the quality of education, evaluation activities have continued almost without interruption. After the transition to remote teaching, we considered it unwise to send out regular surveys and organise teacher-student panel discussions. Somewhat to our surprise, students decided that they wanted to continue the quality evaluation anyway, and organised panel meetings themselves. Surveys are presently conducted as before, with a few additional questions on online teaching. Also, student and teacher panel discussions are online, and provide the feedback in the same way as before the corona pandemic.

As outlined above, meeting the intended learning outcomes (ILOs) has been under pressure since the coronavirus outbreak. Many actions of lecturers, in consultation with the programme management, have led to reasonable solutions. Unfortunately, students have been hindered in their experimental work. However, considering that students spend at least three years to complete their bachelor's programme, we are convinced that the practical skills and competences are sufficiently developed upon graduating. As for internships and contact with the professional field, it has been troublesome to meet the ILOs. Internships abroad have been cancelled, and options are quite limited at the moment. Moreover, company visits and other excursions to external partners have not been possible either. The same holds true for international study tours. We hope, but cannot guarantee, that the many alternative activities, such as online company presentations and research group introductions, can make up for the professional orientation of our graduates.

5. What is the status of student well-being? What has the programme done in this respect?

Our ultimate goal was to limit study delay to an absolute minimum, and to finish the academic year within the originally scheduled time frame. This would give teachers, staff and students the opportunity to get away from study and work for a few weeks during summer. For students, we succeeded in doing so. But quite a number of staff members worked throughout the summer to prepare for the new academic year.
The academic year 2020-2021 started with considerable limitations. Unfortunately, the university remained closed until August 31, which made it impossible for new students to get to know the locations where they would be working and studying. Despite the restrictions before and during the summer period, we were able to connect with the new students during the Kick-In, our yearly introductory period (scaled down significantly due to COVID-19). An introduction meeting in the local cinema, an on-campus introduction to educational systems, a get-to-know-teachers-and-staff bicycle tour around campus and in Hengelo, and a brunch on the O&O square provided many opportunities for students to (safely) meet senior students and staff, and as such become part of the Applied Physics community.
Educational meetings were organised, in which priority was given to on-campus activities, including lab courses, tutorials and project work. All lectures and several tutorials were held remotely and online. To facilitate the online activities, all bachelor and master students received a writing tablet, which was highly appreciated. They are actively used by many students and teachers.
With our first-year students, we started a tutor system. Every ‘doe-groep’ (Kick-In introductory group) was assigned a tutor with whom they meet regularly, typically once a week, to discuss anything related to their academic development. This may be physics-related, but it can also be about other aspects of their student life. The tutor does not take on the role of a mentor; study progress is monitored by the study advisers.
Sadly, halfway the second quarter, we have had to switch all teaching to online again. though practical work , i.e. lab courses and final projects, can optionally be done on campus. Exams are still facilitated on campus. leaving some students and staff with mixed feelings. However, overall they appreciate the on-campus options.

APPENDIX 1.1. DOMAIN SPECIFIC FRAMEWORK OF REFERENCE

This framework defines the knowledge, skills and competences of the graduates from the Applied Physics programmes of the universities of Delft, Eindhoven and Twente. It is formulated for the teaching assessment exercise ('visitatie') round of 2021. The framework is based on the Tuning document of 2018[20], containing criteria for both Bachelor and Master of Physics degrees, with additions to emphasise the skills typical for an *applied* physicist.

Graduates from an Applied Physics Master's programme must have a solid knowledge of physics and they must be capable of applying this knowledge and physicist's skills to make useful contributions at possibly high-level positions in society. A number of alumni will enter further education, which is mostly at the PhD level. The graduates should be competitive on the academic and non-academic job market. The bachelor level should allow students to smoothly enter a Master's programme in Applied Physics, but also in general physics, or other technical programmes at a master level. These bachelor's programmes, together with dedicated follow-up master's programmes, are therefore essential in making them strong competitors on the national and international job market.

Applied physicists distinguish themselves from physicists from non-technical universities by their awareness of, and sensitivity to applications, and the technical skills to realise those applications. What sets Applied Physics apart from other technical disciplines is the higher level of fundamental knowledge, which enables graduates to develop novel techniques and new understanding.

The criteria in the following tables are divided into categories (corresponding to the cells in the second column) and each of these categories is in turn divided into three aspects, which are summarised as 'Knowledge', 'Skills' and 'Autonomy and Responsibility'. The first row gives more elaborate descriptions of these aspects (from the Tuning 2018 document). The criteria 'Design' and 'Technical problem solving and innovation' have been added to better represent the Applied Physics degrees (items 5 and 6 in the tables for the bachelor's and the master's).

The criteria are furthermore placed into categories from the so-called 'Meijers Criteria'[21] (last column), which are tailored to degrees at technical rather than general universities, and from the 'Framework for Qualifications of the European Higher Education Area'[22] (first column).

[20] https://www.calohee.eu/wp-content/uploads/2018/12/WP-4-Del.-1.5-Guidelines-and-Reference-Points-for-the-Design-and-Delivery-of-Degree-Programmes-in-Physics-FINAL-17DEC2018.pdf
[21] 'Criteria for Academic Bachelor's and Master's curricula' https://www.utwente.nl/en/ces/celt/toolboxes/educational-design/1a_course_embedded_in_curriculum/criteria-for-academic-bachelors-and-masters-curricula.pdf
[22] http://ecahe.eu/w/index.php?title=Framework_for_Qualifications_of_the_European_Higher_Education_Area

Table A1.1.1 *Qualifications reference framework for a Bachelor's programme in Applied Physics.*

QF EHEA 1st cycle descriptors		**Knowledge** Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	**Skills** Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	**Autonomy and Responsibilities** - Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts - Take responsibility for managing professional development of individuals and groups	Meijers criteria
I. Have demonstrated knowledge and understanding in a field of study that builds upon their general secondary education, and is typically at a level that, whilst supported by advanced textbooks, includes some aspects that will be informed by knowledge of the forefront of their field of study	1. Theories and Models	Describe the fundamental concepts, laws, models and theories of classical physics and elements of modern physics, as well as their application across a number of real-life situations	Use physical concepts, laws and theories from various domains of physics to model, analyse and explain simple physical phenomena and problems	Identify relevant physics theories and models required to interpret phenomena, observations, and real-life situations.	**I. Is competent in one or more scientific disciplines** A university graduate is familiar with existing scientific knowledge, and has the competence to increase and develop this through study.
II. Can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study	2. Mathematical and computational methods	Name and describe standard mathematical and computational tools methods and their application in the context of physics theories.	Apply standard mathematical and computational tools and methods to solve problems in physics.	Identify and employ standard mathematical and computational tools and methods to solve problems and model situations.	**II. Is competent in doing research** A university graduate has the competence to acquire new scientific knowledge through research. For this purpose, research means: the development of new knowledge and new insights in a purposeful and methodical way.
	3. Experimental design and scientific investigation	Describe standard methods, instrumentation, techniques, theories and regulations used in experimental physics.	Design a simple experimental investigation, using standard instrumentation and follow guidelines, and apply basic methods, techniques and theories for data collection, analysis and reporting.	Set up and carry out simple scientific investigations safely under supervision.	
	4. Problem solving	Link physics concepts and laws with basic strategies, procedures, tools and criteria for framing, representing, solving and validating the results of a problem.	Categorise problems based on physical principles, analyse a problem, recognise its structure and devise a (creative) plan for its solution, execute the devised plan and check for its validity.	Address problems from the point of view of physics, identifying the laws and concepts that apply in a specific situation, devise and carry out a (creative) plan for reaching a solution and check its validity.	
	5. Design	Describe procedures used in design.	Use physics to contribute to solutions design problems.	List examples of and can assess the value of design approaches for physics design.	**III. Is competent in designing** As well as carrying out research, many university graduates will also design. Designing is a synthetic activity aimed at the realisation of new or modified artefacts or systems with the intention of creating value in accordance with predefined requirements and desires (e.g. mobility, health).
	6. Technical problem solving and innovation	Describe strategies for carrying out physics-based innovations and is able to assess the need for those.	Describe possibilities to improve or create new techniques, tools or products. Formulate targets for these and use technical and digital skills to contribute to realize these.	Assess desirability and need for innovation; Can decide whether targets outweigh the anticipated effort.	

III. Have the ability to gather and interpret relevant data (usually within their field of study) to inform judgements that include reflection on relevant social, scientific or ethical issues	7. Scientific culture	Describe the main traits of the historical and epistemological development of physics and relate them to changes and/or issues in technology, society, and the rules of the scientific community.	Select with guidance and use sources of information on the history and current development of physics and on epistemology, and analyse some relevant examples also in relation to technological and societal issues.	Identify some common ideas and approaches in different areas of science also in relation to its historical and epistemological evolution, and evaluate the influence of science on technology and society in some relevant cases.	**IV. Has a scientific approach** A university graduate has a systematic approach characterised the development and use of theories, models and coherent interpretations, has a critical attitude, and has insight into the nature of science and technology.
	8. Work ethic and integrity	State general ethical principles, norms, values, and standards relevant to the work of a physicist, as well as some examples when physics influences health, environment, politics and/or society.	Apply general ethical rules and rules of scientific conduct to the assigned tasks.	Make decisions in line with ethical norms and with regard to civic responsibility, and contribute to local communities and organisations according to own competence.	**V. Possesses basic intellectual skills** A university graduate is competent in reasoning, reflecting, and forming a judgment. These are skills which are learned or sharpened in the context of a discipline, and which are generically applicable from then on.
IV. Can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences	9. Communication	Describe different methods and tools of communication.	Present complex information in a concise manner orally and in writing.	Evaluate scientific material, communicate it orally and in writing in language appropriate for the audience.	**VI. Is competent in co-operating and communicating** A university graduate has the competence of being able to work with and for others. This requires not only adequate interaction, a sense of responsibility, and leadership, but also good communication with colleagues and non-colleagues. They are also able to participate in a scientific or public debate.
	10. Project management and teamwork	Describe strategies for project work and demonstrate attitude to work collaboratively.	Organize and complete a simple project individually or in team, with sensitivity to inclusiveness issues.	Identify and implement an appropriate strategy to carry out a simple individual or group project, collaborate constructively, exercise some initiative and acknowledge accountability for the assigned tasks, with sensitivity for inclusiveness issues.	
V. Have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy	11. Professional development	Identify relevant competences needed for pursuing further studies (career goals), as well as personal strengths, weaknesses and attitudes.	Organise own study and/or learning process, using different kinds of learning materials; evaluate personal work and search for information and support.	Enter new fields of study through a positive attitude, evaluate own personal and professional competences and take responsibility for own learning.	**VII. Takes account of the temporal and the social context** Science and technology are not isolated, and always have a temporal and social context. Beliefs and methods have their origins; decisions have social consequences in time. A university graduate is aware of this, and has the competence to integrate these insights into his or her scientific work.

Table A 1.1.2 *Qualifications reference framework for a Master's programme in Applied Physics.*

QF EHEA 2nd cycle descriptors		**Knowledge** - Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research - Critical awareness of knowledge issues in a field and at the interface between different fields	**Skills** Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	**Autonomy and Responsibilities** - Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches - Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams	Meijers criteria
I. Have demonstrated knowledge and understanding that is founded upon and extends and/or enhances that typically associated with the first cycle, and that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research context	1. Theories and Models	Describe the concepts, laws, models, theories and limitations of classical physics and those of at least one of the specialised cores of modern physics, as well as their application across a wide range of real-life situations and different disciplines.	Use concepts, laws and theories from different domains of physics to model, analyse and explain a wide range of physical phenomena and observations.	Identify relevant theories and models required to interpret phenomena, observations, and real-life situations, also in the context of a different discipline, integrating concepts from different domains of classical and modern physics and recognising the limitations of the different theories and models.	**I. Is competent in one or more scientific disciplines** A university graduate is familiar with existing scientific knowledge, and has the competence to increase and develop this through study.
II. Can apply their knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study	2. Mathematical and computational methods	Name and describe standard mathematical and computational tools and methods and their application in the context of physics theories.	Apply standard and advanced mathematical and computational tools and methods to solve problems in physics.	Identify, adapt, integrate and employ both standard and advanced mathematical and computational tools and methods to solve problems and model situations in a variety of contexts.	**II. Is competent in doing research** A university graduate has the competence to acquire new scientific knowledge through research. For this purpose, research means: the development of new knowledge and new insights in a purposeful and methodical way.
	3. Experimental design and scientific investigation	Describe standard and advanced experimental methods, instrumentation, techniques, theories and regulations used in experimental physics.	Design a complete physics experiment, using standard and advanced instrumentation safely and applying a wide range of methods, techniques and theories for data collection, analysis and reporting.	Set up and carry out scientific investigations independently and safely.	
	4. Problem solving	Link concepts and laws from various domains of physics with advanced strategies, procedures, tools and criteria for framing, representing, solving and validating the results of a problem.	Categorise problems based on physical principles, including complex problems, context-rich problems, and problems derived from unfamiliar contexts; analyse a complex problem, recognise its structure and devise a creative plan for its solution, execute the devised plan and check for its validity.	Address complex problems and situations from the point of view of physics, identifying the laws and concepts that apply even in unfamiliar situations, devise and carry out a creative plan for reaching a solution and check its validity.	
	5. Design	Describe procedures used for design problems for which no unique best solution exists.	Use physics expertise to contribute to solutions for complex design problems.	Assess various design approaches for specific problems involving physics design.	**III. Is competent in designing** As well as carrying out research, many university graduates will also design. Designing is a synthetic activity aimed at the realisation of new or modified artefacts or systems with the intention of creating value in accordance with predefined requirements and desires (e.g. mobility, health).
	6. Technical problem solving and innovation	Assess the quality of techniques, tools or products and the desirability for creating new ones. Know a strategy for carrying out these.	Describe possibilities to improve or create new techniques, tools or products. Formulate targets for this and use technical and digital skills to realize those.	Can assess desirability for improvement; Can decide whether targets outweigh the anticipated effort	

III. Have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgements	7. Scientific culture	Recall focused historical and epistemological facts on the conceptual development of physics theories and relate them to changes and/or issues in technology, society, and the rules of the scientific community.	Select and use different sources of information on the history, epistemology and current development of physics, and analyse different examples also in relation to technological and societal issues.	Identify common ideas and approaches in different areas of science also in relation to its historical and epistemological evolution, and address scientific, technological and societal issues with an informed scientific, historical and epistemological approach.	**IV. Has a scientific approach** A university graduate has a systematic approach characterised the development and use of theories, models and coherent interpretations, has a critical attitude, and has insight into the nature of science and technology.
	8. Work ethic and integrity	State general ethical principles, norms, values, and standards relevant to the work of a physicist, and illustrate different examples when physics influences health, environment, politics and/or society.	Apply general ethical rules and rules of scientific conduct to behaviour in the profession.	Make decisions in line with ethical norms also in research environments and take responsibility for them, and actively contribute to local, national and international communities and (political) organisations according to own competence.	**V. Possesses basic intellectual skills** A university graduate is competent in reasoning, reflecting, and forming a judgment. These are skills which are learned or sharpened in the context of a discipline, and which are generically applicable from then on.
IV. Can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and nonspecialist audiences clearly and unambiguously	9. Communication	Describe the different channels and tools of communication and their limitations.	Communicate effectively to present complex information in a concise manner orally and in writing and using ICT and technical language appropriate for the audience.	Evaluate scientific material and communicate it to a variety of audiences to inform, influence and debate using various techniques and technical language appropriate for the audience.	**VI. Is competent in co-operating and communicating** A university graduate has the competence of being able to work with and for others. This requires not only adequate interaction, a sense of responsibility, and leadership, but also good communication with colleagues and non-colleagues. They are also able to participate in a scientific or public debate.
	10. Project management and teamwork	Describe different project management tools. Have knowledge of and experience with teamwork. Be sensitive to inclusiveness issues.	Engage productively in an individual or group project, handle team conflicts and take inclusiveness issues into account.	Identify and implement an appropriate strategy to carry out an articulated individual or group project, collaborate constructively, perform leading and/or supervisory functions when needed, and take responsibility for the assigned tasks. Influence policies concerning inclusiveness.	
V. Have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous	11. Professional development	Identify relevant competences needed for pursuing further studies (career goals), as well as personal strengths, weaknesses and attitudes.	Organise own study and/or learning process, using different kinds of learning materials; link personal strengths and weaknesses to learning goals and search for learning/career development opportunities	Enter new fields/environments of study or work through a positive attitude, evaluate own personal and professional competences and take responsibility for continuing academic/professional development, also in unfamiliar contexts.	**VII. Takes account of the temporal and the social context** Science and technology are not isolated, and always have a temporal and social context. Beliefs and methods have their origins; decisions have social consequences in time. A university graduate is aware of this, and has the competence to integrate these insights into his or her scientific work.

APPENDIX 1.2. COMPARISON OF FORMER AND REFORMULATED INTENDED LEARNING OUTCOMES

As described with standard 1, the intended learning outcomes (ILOs) of the bachelor's and master's programme were recently reformulated to emphasise the five aspects we value in the development of young academic professionals in the domain of Applied Physics, also with a view to their future development.
Knowledge is important to enable effective communication with peers, but also to make substantiated choices and decisions. **Skills** are equally relevant, and not only relate to the applied physics domain but are considerably broader, specifically extending to the future role in science or industry. The latter also pertains to **personal development**, again in a wide perspective. It not only relates to the discipline, but also to being an academic professional in all aspects, including responsibilities towards science and society. Connected to the above, graduates must be able to effectively **communicate** in different ways, and contribute on the basis of valid, reliable information. Finally, a graduate should be able to **organise** their work, in relation to others, both within and outside the discipline, but, equally important, also in relation to their own personal development. We value a critical attitude towards others, but foremost also with respect to their own continuous development.

Reformulation of the ILOs has been done based on how the curricula have developed over the past years, but also with the goal to be better prepared for the near future. As such, we have taken into account input from students, staff, but also industrial contacts and/or alumni, and of course also the findings of the previous review panel in 2014.

Below, we list the former ILOs of the bachelor's, followed by those of the master's, to end with a table in which they are linked to the reformulated ILOs. For the bachelor's programme, the ILOs are only available in Dutch. As translation is not always straightforward, and may lead to small changes in detail, we choose to include the Dutch version here.

BACHELOR'S PROGRAMME

De afgestudeerde van de bacheloropleiding Technische Natuurkunde:

A. heeft een gedegen theoretische en praktische basiskennis van de (technische) natuurkunde in samenhang met de daarvoor benodigde wiskunde en informatica, die toereikend is om met succes een natuurkundige Masteropleiding te selecteren en te volgen;
B. heeft voldoende inzicht in de diverse specialisaties van de (technische) natuurkunde die voortbouwen op bacheloropleiding om een verantwoorde keuze te maken voor een vervolgstudie;
C. heeft kennis gemaakt met wetenschappelijke onderzoekvaardigheden en methoden op het gebied van de natuurkunde en is in staat basale fysische problemen in een beperkte context te herkennen, te analyseren en met wiskundige hulpmiddelen (inclusief computertoepassingen) op te lossen;
D. is in staat het ontbreken van benodigde vakkennis en vaardigheden te onderkennen en deze zelfstandig te verwerven en te integreren in reeds opgedane kennis en vaardigheden;
E. beheerst de algemene vaardigheden op het gebied van presenteren en rapporteren, informatie zoeken en verwerken, computergebruik, projectmatig werken en werken in teams;
F. is zich bewust van de mogelijkheden op de arbeidsmarkt na een eventuele afsluiting van de studie met het bachelordiploma;
G. is zich bewust van de rol en positie van de natuurkunde in de wetenschap en de maatschappij en van het internationale karakter van de natuurkunde.

MASTER'S PROGRAMME

A. The required level of physics during and after the programme is determined nationally and internationally. In view of the objectives of the programme, education is aimed at acquiring:
B. Thorough knowledge of the basic theories in the domain of physics and mathematics;
C. Thorough knowledge of one or more sub-areas in the physics domain;

D. Knowledge of physics technology, including skills for designing and using measurement instruments and experimental techniques;
E. Orientation into the application areas of Applied Physics;
F. Insight in the interrelation between sciences and the relationship between sciences, and the resulting responsibilities;
G. Skills such as being able to independently acquire knowledge; being able to creatively and systematically contribute to resolving problems in the field; being able to cooperate with colleagues and non-colleagues; and communicational, social and organizational skills.

Table A1.2.1 *Comparison of the former ILOs as they are described in the 2020-2021 EER to the reformulated ILOs as presented with standard 1.*

Bachelor	Master	BSc	MSc
Knowledge – The Applied Physics graduate:			
has comprehensive technical and scientific knowledge of the relevant fields in (applied) physics in combination with relevant mathematics and computer science	has thorough technical and scientific knowledge of essential theories in the domain of (applied) physics and mathematics, and can relate to other disciplines in a multidisciplinary environment	A	A
is aware of the various specialisations in the domain of (applied) physics, and their relevance in industry and academia	has advanced knowledge and understanding and the ability to apply this knowledge to design and research within one or more sub-areas of the (applied) physics domain	B	B
Skills – The Applied Physics graduate:			
can apply basic mathematical, experimental and computational tools and methods to solve problems in physics	can apply advanced mathematical, experimental and computational tools and methods to solve complex physical problems in a broad context	A,C	A,C
is familiar with scientific research methods within the physics domain and can identify basis physics problems in a limited context	can apply the scientific research method and identify advanced physics problems in their full context	C	C
can contribute to the solution of research or design problems in the field of engineering physics using a systematic approach	can identify, formulate and solve research or design problems in the field of (engineering) physics using a systematic approach.	C	C,D,F
is aware of the scientific design method and can use physics to contribute to innovative solutions and verify their validity	can apply the scientific design method, divide a design problem into different sub-problems, and can apply physics expertise to realize complex innovative solutions	-	C
Personal development – The Applied Physics graduate:			
is critical, self-thinking, and able to reflect on their own performance and personal responsibilities		-	E
is aware of the role of applied physics in science and society, and of the international orientation of the discipline		G	E
is aware of the possibilities on the labour market or to continue studying with an academic master, after completing the bachelor's programme	has experience with the possibilities on the labour market and in academia after completing the master's programme	F	-
can decide based on integrity and take responsibility for their own performance	can decide based on integrity and ethical norms also in research and industrial environments and take responsibility in a local, national and international setting	-	-
can select, process and evaluate information from different sources		E	-
Communicating – The Applied Physics graduate:			
can effectively communicate on technical-scientific topics orally and in writing in a professional manner	can effectively communicate with a variety of audiences to inform, influence and discuss using various techniques and language appropriate for the audience	E	F
Organizing – The Applied Physics graduate:			
can organize and complete a simple project individually or as part of a team by collaborating, taking initiative and being sensitive to inclusivity issues	can organize, contribute to and complete a complex project, either individually or as part of a team by collaborating, taking the lead and being sensitive to inclusivity issues	E	F
has the attitude to learn and is able to maintain, improve and integrate new knowledge and academical skills into existing competences		D	F
can identify relevant competences for further development after completing the academic programme, and can link strengths and weaknesses to personal and professional development goals (life long learning)		-	-

APPENDIX 2.1. DETAILED OVERVIEW OF THE BACHELOR'S PROGRAMME

DETAILED OVERVIEW OF THE BACHELOR'S PROGRAMME

In chapter 2, the bachelor's curriculum was presented. Here we provide more detailed information on the content and structure of the bachelor's programme in Applied Physics. Also, we outline the learning lines and cohesion within the programme and give an overview of the study load in terms of contact hours.

YEAR 1

The first year is designed to allow further development of what was learned in high school and to explore the broad field of Applied Physics from different perspectives. In each module, students focus on a particular aspect of applied physics, and their team projects have a direct link to the main themes in the various modules.

In the first module everything revolves around dynamics. Besides content knowledge and skills, this module also allows students to familiarise themselves with setting up and performing a scientific experiment and how to report on the results. The second module focusses on thermodynamics and thermodynamic cycles, including the math required to solve thermodynamic problems and lab experiments on different ways of heat transport. For their group project students design, build and test a thermodynamic system, such as a cooler or an energy storage system. The third module is about electricity and magnetism and is largely shared with the Applied Mathematics programme. In this module, students work on recreating and modelling a historical experiment that led to the formulation of a core concept in electromagnetism. The fourth module provides an introduction to quantum mechanics, in which students learn to relate properties of materials to their structure on an atomic scale. In addition, the module includes experimental work on optical systems and students develop their own system using integration of signals.

YEAR 2

In the second year, everything revolves around broadening and deepening the knowledge gained in the first year. Students are introduced to three important research areas, i.e. optics, materials physics and physics of fluids.

The fifth module introduces students to the principles of modelling and analysing dynamic systems. In this module, students can choose to take one of two courses: the more fundamental Classic Mechanics and the more applied Engineering Solid Mechanics. During the sixth module, the basic principles of quantum mechanics are discussed, and in particular the interpretation of the quantum mechanical wave function. In module 7 the central theme is physics of condensed matter, from which various new research fields have emerged including nanotechnology, solar energy and spintronics. The module comprises courses in solid state physics, statistical physics and partial differential equations. Finally, module 8 has a strong focus on continuum dynamics, including courses on electrodynamics and physics of fluids.

YEAR 3

The third year of the bachelor's allows for differentiation depending on the interests of the student. For modules 9 and 10, students choose a minor programme of 30 EC. This can be a broadening minor in a different discipline, but also an in-depth minor within a specific area of Applied Physics, such as for example Soft and Biological Physics. Alternatively, the minor can be followed abroad, as an exchange programme at another university. Students can also use their minor to obtain their first teaching degree or devote one of minor modules to a large student project, such as the Roboteam Twente or the Green Team.

Module 11 concentrates on the preparation of the bachelor assignment and on making an informed choice for a next career step, either a subsequent master or a job outside academia. To support the latter, in module 11 we offer a range of electives, such as Materials Science, Technical Optics, Computational Physics, Machine Learning or Soft Matter, enabling students to explore the options after their bachelor's programme. In consultation with the Board of Examiners students can select other courses, which prepare them even better for their further career choice. Finally, module 12 is entirely dedicated to the bachelor assignment. For this assignment, students work on an individual research project within one of the research groups of Applied physics, in which they apply the knowledge and skills developed during the entire bachelor's programme. More information on the bachelor assignment is provided in section 3.3.

COHESION AND LEARNING LINES

With the implementation of the Twente Education Model (TOM), the Applied Physics bachelor curriculum was redesigned creating modules in which various topics are taught in a coherent way. Each module is devoted to a specific theme on which the project (in modules 1-5) is based. Other components of the module, such as physics and mathematics courses, lab course assignments and programming exercises provide students with knowledge and skills they need to approach the project. Cohesion of the different topics taught within a module is essential. The competence to solve complex problems benefits substantially by integration of theory and practice and application to challenges posed by the project.

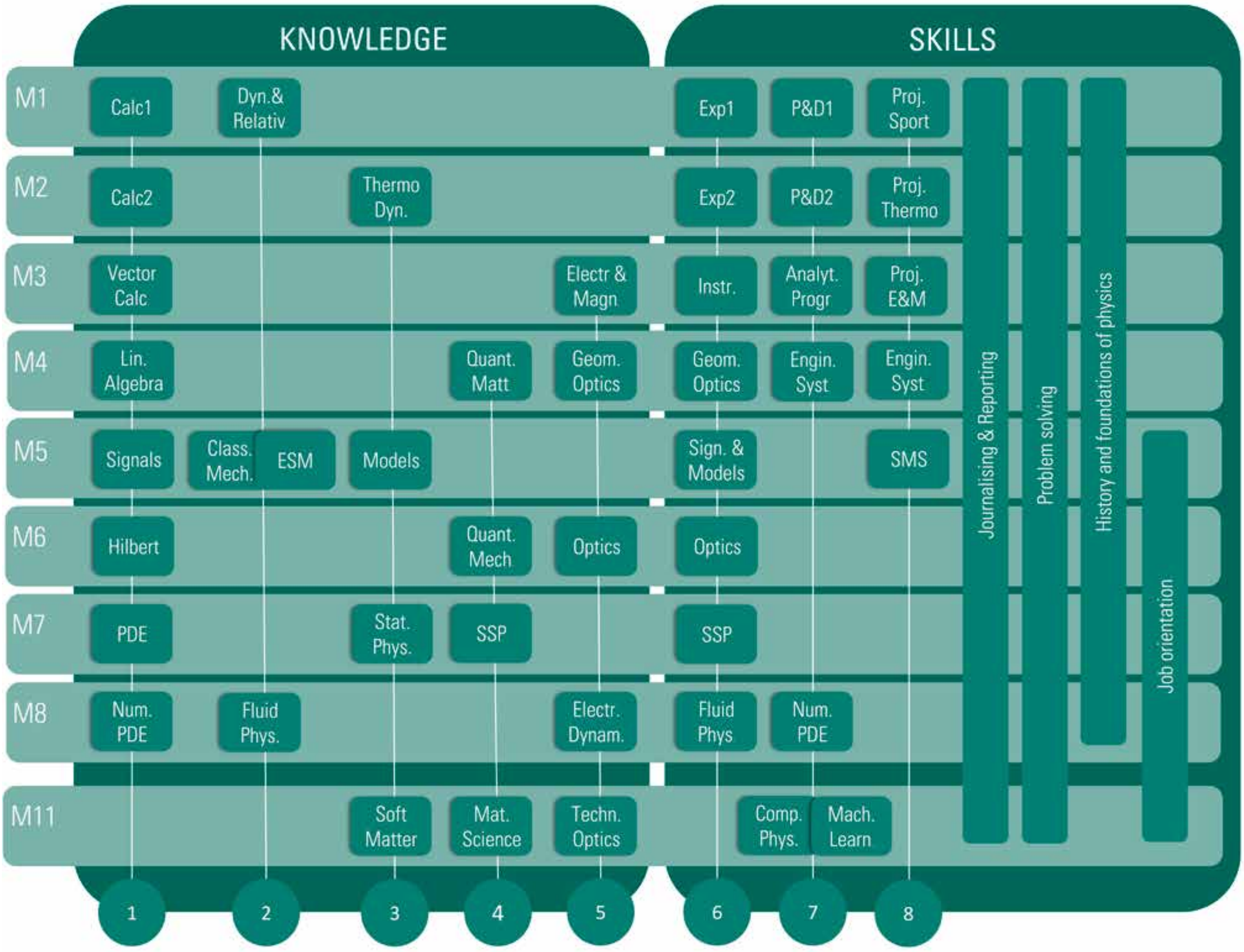


Figure A2.1.1 *Cohesion and learning trajectories in the Bachelor's programme Applied Physics. Numbers indicate various learning lines: 1. Mathematics, 2. Dynamics, 3. Thermodynamics, 4. Quantum Mechanics and Materials Physics, 5. Electromagnetism and Optics, 6. Experimental skills, 7. Programming skills, 8. Project skills.*

Modules 6-8 are organised somewhat differently. They comprise a fundamental physics course of 6 EC (Quantum Mechanics, Statistical Physics and Electrodynamics, respectively, in the three modules), a mathematical physics course of 2 EC, and an integrating course of 7 EC. This integrating course is closely related to research domains within Applied Physics, i.e. Optics, Materials Physics, and Fluid Physics, and consists of a theory and an experimental part (approx. 70% and 30%, respectively).

Integration is not only achieved within modules, but also by carefully designing the various learning lines with respect to each other. An overview is given in figure A2.1.1, in which the different learning lines are grouped into knowledge and skills. The module components are grouped horizontally, while the sequential relation between the courses is indicated by vertical connections. In the knowledge-related learning lines, the sequential order of required courses is taken into account. This obviously applies for many of the physics courses (for example, Thermodynamics – Statistical Physics – Soft Matter, Quantum Matter – Quantum Mechanics, Dynamics & Relativity – Fluid Physics and Geometrical Optics – Optics). But also, the interrelation between for example mathematics and physics is accounted for. As an example, in Calculus 1 not only vectors and their products are taught (needed for Dynamics & Relativity), but also most of the required differential calculus required for Thermodynamics is treated. Likewise, in Calculus 2 the integral calculus needed to start Electricity and Magnetism is taught, leaving only the more advanced topics for Vector Calculus in module 3.

Although learning trajectories related to skills are shown separately in figure A2.1.1, there is a strong interrelation between experimenting, programming and project skills. Obviously, this also holds for the 'Journalising and reporting' line. The experimental learning line focusses on setting up, preparing, executing and analysing a physics experiment. Computational skills are developed in the programming line. Students start by learning Python and then Mathematica, to support physics theory and experiment, followed by applying these computational tools in basic courses such as Vector Calculus, Electricity & Magnetism, and Quantum Mechanics. Later in the programme, more advanced application of computational skills in elective courses such as Computational Physics or Machine Learning is possible.
Project skills encompass a variety of competences required to solve complex problems in a team of scientists, at first only physicists but later also with students from other disciplines. It requires organisation skills, such effective communication and conducting meetings, but of course student should be aware of their own personal contribution and role, also in relation to others in the team. Finally, in the 'History and foundations of physics' learning line, activities are aimed at placing the module themes in a historical perspective, for example by guest lectures, a visit to a (science) museum or a dedicated symposium.

For every module a dedicated Canvas site is available, which contains all course material related to the knowledge intensive topics. The material related to the skills learning lines is collected on a separate Canvas site 'Academic skills'. Every year a new Canvas site is initiated, which is filled with relevant material during the sequential modules and effectively 'develops' along with the students in that cohort.

STUDY LOAD AND CONTACT HOURS

The study load for every module amounts to 15 EC, equivalent to 420 hours nominal study time[23]. The contact hours in the bachelor's programme are distributed over lectures, tutorials (including guided self-study), lectorials, lab courses, project and exams. The project includes workshops, feedback sessions and presentation seminars. 'Other' refers to Q&A sessions, module introductions and other informative session.

An overview of the contact hours in the first two years are summarised in table A2.1.1. In the first year, contact hours amount to approximately 50-60% of the nominal study duration. In the second years this drops to 40-50%, which is in line with our aim to enhance autonomous learning of our students. The contact hours in modules 9 and 10 depend considerably on the choices that students make for their minor. The same holds for module 11, for which we only include the scheduled hours for the Preparation Bachelor Assignment course. Students typically take 2 electives with strongly varying contact hours. The bachelor assignment in module 12 is full time; the number of contact hours strongly depends on the type of assignment, activities and supervisors.

[23] A study load of 1 EC amounts to 28 hours nominal study duration.

Table A2.1.1 *Overview of contact hours in the bachelor's programme, in the academic year 2019-2020.*
Hours for exams do not include resits. The total percentage is relative to the nominal study load of 420EC for each module. For module 11, only the contact hours are listed for Preparation Bachelor Assignment are provided (nominal study load 5 EC = 140 hours).

	Lecture	Tutorial	Lectorial	Lab course	Project	Other	Exam	Total
Module 1	42	78	8	36	10	19	7	200 (48%)
Module 2	37	66	28	36	40	26	15	248 (59%)
Module 3	52	52	18	52	25	16	10	225 (54%)
Module 4	48	58	14	24	28	21	8	201 (48%)
Total year 1	179	254	68	148	103	82	40	874 (52%)
Module 5	45	54	50	20	14	3	9	195 (46%)
Module 6	-	-	136	24	-	17	9	186 (44%)
Module 7	32	16	68	24	-	16	9	165 (39%)
Module 8	52	58	36	30	-	6	6	188 (45%)
Total year 2	129	128	290	98	14	42	33	734 (44%)
Module 9 & 10	Minor: contact hours are different for every student							
Module 11	-	-	16	-	-	26	-	42 (30%)

APPENDIX 2.2. DETAILED OVERVIEW OF THE MASTER'S PROGRAMME

DETAILED OVERVIEW OF THE MASTER'S PROGRAMME

In chapter 2, the master's programme was presented with a brief summary of the curriculum. Here we provide more detailed information on the content and structure of the master's curriculum, including an overview of the specialisation courses. In addition, to show how teaching aligns with our aim to educate academic professionals, the relation between the specialisation courses and the intended learning outcomes is briefly indicated. Also, the study load in terms of contact hours is reviewed. We finish by giving an overview of the pre-master and homologation programme for students with an Applied Physics or Electrical Engineering qualification in higher professional education, i.e. with a degree from a University of Applied Sciences.

CURRICULUM

In table A2.2.1 an overview of the master's curriculum is given. Generally, the first year of the programme consists of courses, which can be equally divided into compulsory courses, specialisation courses and electives. The compulsory courses cover the important aspects of the Applied Physics programme. Applied Quantum Mechanics provides a more solid basis in this fundamental topic, building on the courses given in the bachelor phase of any physics curriculum. Mathematical and Numerical Physics is aimed at highlighting these tools in relation to a number of timely examples and at the same time challenges students to further develop their computational skills. Heat and Mass Transfer is focussed on engineering physics, while Small Signals and Detection is devoted to experimental physics. An extended lab course assignment is part of the latter course. Finally, the awareness of students for ethical and cultural aspects is raised by a number of group sessions and an assignment. A major benefit of the compulsory courses for all students is that in every quarter they have a class together with their peers.

Table A2.2.1 *Curriculum of the Master's programme Applied Physics.*
The prolonged internship (10 EC) is at the expense of the electives in the first year.

Year 1		
Compulsory courses		20 EC
Applied Quantum Mechanics	5.0 EC	
Mathematical and Numerical Physics	5.0 EC	
Heat and Mass Transfer	5.0 EC	
Small Signals and Detection	4.0 EC	
Ethical and Cultural Awareness	1.0 EC	
Specialisation courses		20 EC
Elective courses Physical/Technical		10 EC
Elective courses free		10 EC
Year 2		
Internship		20 EC (or 30 EC)
Master assignment		40 EC
General aspects	50%	
Physics aspects	50%	

We will touch upon the specialisation courses below. For the elective courses, students must at least choose 10 EC in the physical and/or technical domain and may select up to 10 EC from other programmes. The second year is fully devoted to the internship and the master assignment. Details on where students do their internship was described in chapter 4.
The final assignment is performed on a research topic, either within one of the Applied Physics chairs or elsewhere, at an institute or a company. In the latter case, supervision from within Applied Physics guarantees sufficient level and depth.

As mentioned in chapter 2, with the revision of the master's curriculum in 2018 we also moved away from the former tracks devoted to Materials Physics, Fluid Physics, and Optics and Biophysics. The tracks proved not to be in line with developments in focus of research and the formation of clusters. To provide a more specific preparation for the graduation assignment in one of the Applied Physics groups, the chairs were asked to provide a list of (at most) 20 EC of specialisation courses, which students should take to be able to work in their group. The results are summarised in tables A2.2.2 – A2.2.6, in which the different groups are listed within their research cluster.

Table A2.2.2 *Chair-specific specialisation courses in the Applied Nanophotonics cluster.*

Adaptive Quantum Optics (AQO), prof.dr. P.W.H. Pinkse	
Wave Optics	5.0 EC
Quantum Optics	5.0 EC
course in consultation with the chair	5.0 EC
choice 1 out of 3: Integrated Optics Laser Physics Nonlinear Optics	5.0 EC
BioMedical Photonic Imaging (BMPI), prof.dr.ir. W. Steenbergen	
Wave Optics	5.0 EC
Biomedical Optics	5.0 EC
Medical Acoustics	5.0 EC
one of the recommended elective courses	5.0 EC
COmplex Photonic Systems (COPS), prof.dr. W.L. Vos	
Wave Optics	5.0 EC
Quantum Optics	5.0 EC
Nanophotonics	5.0 EC
Nanophotonic experiments	5.0 EC
Laser Physics and Nonlinear Optics (LPNO), prof.dr. K.L. Boller	
Laser Physics	5.0 EC
Wave Optics	5.0 EC
Nonlinear Optics	5.0 EC
Experimental Laser Physics and Nonlinear Optics	5.0 EC
Optical Sciences (OS), prof.dr.ir. H.L Offerhaus	
Wave Optics	5.0 EC
Integrated Optics	5.0 EC
one of the recommended elective courses	2.5/5.0 EC
choice 1 out of 2: Laser Physics Nonlinear Optics	5.0 EC

Table A2.2.3 *Chair-specific specialisation courses in the Energy, Materials and Systems cluster.*

Energy, Materials and Systems (EMS), prof.dr.ir. H.J.M. ter Brake	
Introduction to Superconductivity	5.0 EC
Applications of Superconductivity	5.0 EC
Cryogenic Science and Technology	5.0 EC
course in consultation with the chair	5.0 EC

Table A2.2.4 *Chair-specific specialisation courses in the NanoElectronic Materials cluster.*

Computational Chemical Physics (CCP), prof.dr. C. Filippi	
Advanced Quantum Mechanics	5.0 EC
Theoretical Solid State Physics	5.0 EC
Computational Physics	5.0 EC
course in consultation with the chair	5.0 EC
Computational Materials Science (CMS), prof.dr. P.J. Kelly	
Theoretical Solid State Physics	5.0 EC
Electronic Structure Theory 1	5.0 EC
Electronic Structure Theory 2	5.0 EC
Nanophysics	5.0 EC
Industrial focus group XUV (XUV), prof.dr. M.D. Ackermann	
Nanophysics	5.0 EC
Surfaces and Thin Layers	5.0 EC
AMM-Inorganic Materials Science	5.0 EC
course in consultation with the chair	5.0 EC
Inorganic Materials Science (IMS), prof.dr. A.J.H.M. Rijnders	
AMM-Characterisation	5.0 EC
AMM-Inorganic Materials Science	5.0 EC
course in consultation with the chair	5.0 EC
choice 1 out of 3: Surfaces and Thin Layers Wave Optics Solar Energy	5.0 EC
Interfaces and Correlated Electron Systems (ICE), prof.dr.ir. J.W.M. Hilgenkamp	
Theoretical Solid State Physics	5.0 EC
Nanophysics	5.0 EC
Introduction to Superconductivity	5.0 EC
course in consultation with the chair	5.0 EC
Physics of Interfaces and Nanomaterials (PIN), prof.dr.ir. H.J.W. Zandvliet	
Nanophysics	5.0 EC
Surfaces and Thin Layers	5.0 EC
Modern Topics in Condensed Matter Physics	5.0 EC
course in consultation with the chair	5.0 EC
Quantum Transport in Matter (QTM), prof.dr.ir. A. Brinkman	
Theoretical Solid State Physics	5.0 EC
Nanophysics	5.0 EC
Introduction to Superconductivity	5.0 EC
course in consultation with the chair	5.0 EC

Table A2.2.5 *Chair-specific specialisation courses in the Physics of Fluids cluster.*

Physics of Fluids (POF), prof.dr. D. Lohse	
Advanced Fluid Mechanics	5.0 EC
Experimental Techniques in Physics of Fluids	5.0 EC
choice of 10 EC from: Capillarity Phenomena 5.0 EC Turbulence 5.0 EC Granular Matter 5.0 EC Fluids and Elasticity 2.5 EC Physics of Bubbles 2.5 EC Medical Acoustics 5.0 EC 1 out of 2 (not both, due to overlap): Numerical Methods for Engineers 5.0 EC Computational Fluid Dynamics 5.0 EC	10.0 EC

Table A2.2.6 *Chair-specific specialisation courses in the Soft Mater cluster.*

BioElectronics (BE), prof.dr. S.J.G. Lemay	
Soft Matter Physics	5.0 EC
Physical Biology	5.0 EC
Ions and Devices	5.0 EC
Nanofluidics	5.0 EC
NanoBioPhysics (NBP), prof.dr. M.M.A.E. Claessens	
Physical Biology	5.0 EC
Biomedical Acoustics	5.0 EC
courses in consultation with the chair	10.0 EC
Physics of Complex Fluids (PCF), prof.dr. F.G. Mugele	
Capillarity Phenomena	5.0 EC
Nanofluidics	5.0 EC
Soft Matter Physics	5.0 EC
course in consultation with the chair	5.0 EC

COHESION AND LEARNING LINES

As outlined above, the general compulsory courses provide a broad overview of fundamental and engineering physics, and at the same time focus on mathematical, experimental and computational skills at an advanced level. The specialisation courses can be clustered in various research domains within the discipline, therewith providing in-depth knowledge on sub-areas of Applied Physics. In general, the specialisation courses are taught by our teaching staff, who are at the same time our top-scientists. Combined with the small scale of the programme and relatively small number of students in every course, the master-apprentice approach runs throughout the curriculum and guarantees the academic level and orientation. This is also reflected in the fact that the teaching activities often include many (homework) exercises, and seminars in which students present and discuss the topics of a particular course.

Despite the fact that there are no clearly defined learning lines in the master's curriculum, it is obvious that the combined teaching of various courses together contributes to the intended learning outcomes (ILOs). In table A2.2.7 we attempt to provide an overview of how the various specialisation courses contribute to the ILOs. A similar overview was already provided in table 2.4 for the compulsory courses.

STUDY LOAD AND CONTACT HOURS

The total study load of the master's amounts to 120 EC, i.e. equivalent to two years nominal study duration. As in the bachelor, the contact hours in the master's programme are distributed over lectures, tutorials, lectorials, lab courses, exams, and presentation seminars. As outlined in the previous section, the individual study planning of students is very diverse due to the many specialisation options and choices for electives. Therewith, the number of contact hours also varies considerably, and it is difficult to precisely indicate the number of contact hours in the first year. Attempting to make a rough estimate, we may consider that for the compulsory courses 3 teaching activities of 2 hours each are scheduled weekly, in the first 8 weeks of every quarter, with a 3 hour exam or presentation seminar in the last week. This sums up to approximately 50 contact hours. For the specialisation and elective courses, on average 2 teaching activities are scheduled weekly for each course. Including the exam or presentation seminar, this sums up to about 35 hours per course. This all adds up to 120 contact hours in a quarter, which is equivalent to a little less than 30% of the nominal study duration. As expected, this is significantly less than in the bachelor's programme.

The internship and master assignment are in principle full time activities; the number of contact hours strongly depends on where the internship is done or the type of assignment, and of course what has been agreed with supervisors. Generally, in line with a more autonomous way of working, contact hours will be considerably less in the master assignment as compared to the bachelor assignment.

Table A2.2.7 *Relation between the ILOs and the various specialisation courses.*

Educational units	Advanced Fluid Mechanics	AMM-Characterisation	AMM-Inorganic Materials Science	Applications of Superconductivity	Biomedical Optics	Capillarity and Wetting Phenomena	Computational Physics	Cryogenic Science and Technology	Electronic Structure Theory I and II	Exp. Laser Phys. and Nonlinear Optics	Exp. Techniques in Physics of Fluids	Fluids and Elasticity	Granular Matter	Introduction to Superconductivity	Ions and Devices	Laser Physics	Medical Acoustics	Modern Topics in Cond. Matter Phys.	Nanofluidics	Nanophotonics	Nanophotonics Experiments	Nanophysics	Nonlinear Optics	Physical Biology	Physics of Bubbles	Quantum Optics	Solar Energy	Soft Matter Physics	Surfaces and Thin Layers	Theoretical Solid State Physics	Turbulence	Wave Optics
Knowledge																																
technical and scientific knowledge and multidisciplinarity	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
advanced knowledge and understanding applied in sub-area(s)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Skills																																
mathematical, experimental, computational tools to solve problems	X		X		X	X	X		X		X	X	X			X	X	X	X	X	X	X			X	X	X	X		X	X	X
scientific research methods and identify advanced problems		X		X		X			X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
identify, formulate, solve research/design problems	X	X			X		X	X	X	X	X		X			X	X	X	X		X	X	X	X	X	X	X		X	X	X	X
scientific design method and contribute to innovative solutions	X							X	X	X	X					X	X	X			X		X		X		X					X
Personal development																																
critical, self-thinking, and able to reflect		X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
applied physics in science, society, and international orientation				X	X			X	X		X	X	X	X		X	X	X		X	X	X	X	X	X	X	X		X	X	X	X
experience with labour market and/or academia after master's												X				X	X						X				X					X
decide based on integrity, ethical norms and take responsibility														X		X		X					X				X					
select, process and evaluate information from different sources			X	X		X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Communication																																
effectively communicate orally and in writing				X	X	X	X			X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X
Organisation																																
organise and lead complex project individually or as part of a team										X	X		X					X			X						X				X	X
attitude to learn and integrate knowledge and skills				X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X
identify competences for development (life-long learning)								X	X		X		X		X	X	X	X		X	X	X	X				X			X		X

PROGRAMME FOR STUDENTS WITH A QUALIFICATION IN HIGHER PROFESSIONAL EDUCATION (HBO)

Students with a qualification in higher professional education (University of Applied Sciences; hbo) in Applied Physics or Electrical Engineering are admissible to a transfer programme of 30 EC, as summarised in table A2.2.8.

Table A2.2.8 *Pre-master's programme for students with a hbo degree in Applied Physics or Electrical Engineering.*

PREMASTER PROGRAMME APPLIED PHYSICS			
Quarter 1		Quarter 2	
Calculus A	4.0 EC	Calculus B	3.0 EC
Linear Algebra	3.0 EC	Quantum Mechanics	6.0 EC
Models	4.5 EC	Optics	4.5 EC
Introduction Solid State Physics	5.0 EC		

After completion of the transfer programme, candidates can be admitted to the Master's programme in Applied Physics at the University of Twente. The programme for students with a qualification in higher professional education in Applied Physics or Electrical Engineering is summarised in table A2.2.9. The general physics courses, which are part of our bachelor's, constitute the homologation programme. In order to be able to include these courses in the 120 EC programme, the internship (20 EC) and the free electives (10 EC) are omitted for these students.

Table A2.2.9 *Master's programme for students with a hbo degree after completing the pre-master's programme outlined in table A2.2.8.*

General physics courses		30 EC
Electricity and Magnetism	5.0 EC	
Statistical Physics	6.0 EC	
Electrodynamics	6.0 EC	
Fluid Physics	7.0 EC	
Hilbert Space	2.0 EC	
Partial Differential Equations	2.0 EC	
Numerical Methods for PDE	2.0 EC	
Compulsory courses		20 EC
Applied Quantum Mechanics	5.0 EC	
Mathematical and Numerical Physics	5.0 EC	
Heat and Mass Transfer	5.0 EC	
Small Signals and Detection	4.0 EC	
Ethical and Cultural Awareness	1.0 EC	
Specialisation courses		20 EC
Elective courses Physical/Technical		10 EC
Master assignment		40 EC
General aspects	50%	
Physics aspects	50%	

APPENDIX 2.3. OVERVIEW OF THE STAFF INVOLVED IN THE APPLIED PHYSICS PROGRAMME

In table A2.3.1 we list the staff responsible for teaching in our bachelor's and master's programme, including their affiliation and the courses they are involved in. For staff members within the Applied Physics domain, their possible role[24] in bachelor and master assignment committees is indicated. As indicated with standard 3, the list of Applied Physics staff and their roles is approved twice a year by the Board of Examiners.
Every chair in the Applied Physics domain has an associated Capita Selecta-course, which can be adjusted to the individual needs of students. This pertains to content, activities and assessment. These Capita Selecta-courses are not listed in the overview.

Table A2.3.1 *Teaching staff in the Applied Physics programme*

			BSc assign.		MSc Assign.			
Name	Position	Affiliation	Chair	Ref. member	Chair	Ref. member	Internship supervisor	Courses Applied Physics
Prof.dr. M.D. Ackermann	Full prof.	TNW-XUV	X	X	X	X	X	M: Surfaces and Thin Layers
Dr. J.A. Alvarez Chavez	Assist. prof.	TNW-OS	X	X		X	X	
Prof.dr. W.L. Barnes	Guest prof.	TNW-COPS	X		X			M: Nanophotonics Experiments
Dr.ing. H.M.J. Bastiaens	Researcher	TNW-LPNO	X	X		X	X	M: Experimental Laser Physics and Nonlinear Optics
Dr. M. Bayraktar	Assist. prof.	TNW-XUV	X	X		X	X	B: M04: Engineering Systems M05: Signals
Dr.ir. W.T.E. van der Beld	Assist. prof.	TNW-XUV	X	X		X	X	
Prof.dr. F. Bijkerk	Full prof.	TNW-XUV	X	X	X	X	X	
Dr. C. Blum	Assist. prof.	TNW-NBP						M: Biophysical Techniques and Molecular Imaging Quantum Emitters
Dr.ir. M. Bokdam	Assist. prof.	TNW-CMS	X	X		X	X	M: Machine Learning (also B-TN M11 elective)
Prof.dr. K. Boller	Full prof.	TNW-LPNO	X	X	X	X	X	B: M03: Electromagnetics M11: Technical Optics M: Experimental Laser Physics and Nonlinear Optics Laser Physics Nonlinear Optics
Dr.ir. N. Bosschaart	Assoc. prof.	TNW-BMPI	X	X		X	X	
Prof.dr.ir. H.J.M. ter Brake	Full prof.	TNW-EMS	X	X	X	X	X	B: M02: Module coordinator M02: Project Thermodynamics M: Cryogenic Science and Technology
Prof.dr.ir. A. Brinkman	Full prof.	TNW-QTM	X	X	X	X	X	B: M04: Module coordinator M04: Quantum Matter M06: Quantum Mechanics M11: Materials Science M: Introduction to Superconductivity
Prof.dr. G.H.L.A. Brocks	Full prof.	TNW-CMS	X	X	X	X	X	B: M08: Electrodynamics M: Advanced Quantum Mechanics Computational Physics (also B-TN M11 elective) Electronic Structure Theory II Mathematical and Numerical Physics
Dr. L. Chang	Assist. prof.	TNW-OS	X	X		X	X	
Prof.dr. M.M.A.E. Claessens	Full prof.	TNW-NBP	X	X	X	X	X	M: Physical Biology
Dr. T.S. Craig	Lecturer	EEMCS-AA						B: M04: Linear Algebra
Dr. R.M.J. van Damme	Assoc. prof.	TNW-CCP	X	X		X	X	B: M06: Hilbert Space M: Machine Learning (also B-TN M11 elective) Mathematical and Numerical Physics Theory of General Relativity

[24] Details on who can take on specific roles are summarised in the Rules of the Board of Examiners and its internal rules.

Name	Position	Affiliation	BSc assign.		MSc Assign.		Internship supervisor	Courses Applied Physics
			Chair	Ref. member	Chair	Ref. member		
Dr. M.M.J. Dhallé	Assoc. prof.	TNW-EMS	X	X		X	X	B: M03: Electromagnetics M03: Instrumentation M03: Project Electromagnetism and Measurements M: Applications of Superconductivity Electrical Power Engineering and System Integration Introduction to Superconductivity
Dr. D. Djokovic	Study advisor	TNW-AP		X		X	X	B: M01: Project Dynamics and Relativity M02: Project Thermodynamics M03: Project Electromagnetism and Measurements M11: Preparation Bachelor Assignment
Dr. M.G.H. Duits	Assoc. prof.	TNW-PCF	X	X		X	X	B: M09: Module coordinator (minor Applied Physics) M09: Advanced Colloids and Interfaces M09: Soft and Biological Techniques M: Physical Biology Soft Matter Physics (also B-TN M11 elective)
Prof.dr.ing. B. van Eijk	Part-time prof.	TNW-EMS	X	X	X	X	X	M: Introduction to High Energy Physics
Dr. C.I. van Emmerik	Study adviser	TNW-AP		X		X	X	B: M01: Project Dynamics and Relativity M02: Project Thermodynamics M03: Project Electromagnetism and Measurements M06: Optics M11: Preparation Bachelor Assignment
Dr. H.T.M. van den Ende	Guest lecturer	TNW-PCF	X	X		X	X	B: M07: Statistical Physics
Prof.dr. C. Fallnich	Full prof.	TNW-LPNO	X	X	X	X	X	
Prof.dr. C. Filippi	Full prof.	TNW-CCP	X	X	X	X	X	B: M05: Classical Mechanics M: Computational Physics (also B-TN M11 elective) Mathematical and Numerical Physics
Prof.dr. S.M. García Blanco	Adjunct prof.	TNW-OS	X	X	X	X	X	M: Experimental Laser Physics and Nonlinear Optics Integrated Optics Nano-Optics
Prof.dr.ir. B.J. Geurts	Full prof.	EEMCS-MMS						B: M07: Partial Differential Equations M08: Numerical Methods for PDE
Dr. A.A. Golubov	Assoc. prof.	TNW-ICE	X	X		X	X	M: Introduction to Physics of Correlated Electrons Introduction to Superconductivity Nanophysics
Prof.dr.ir. J.W.M. Hilgenkamp	Full prof.	TNW-ICE	X	X	X	X	X	B: M11: Materials Science M: Introduction to Superconductivity
Dr. M.A. van der Hoef	Assoc. prof.	TNW-POF	X	X		X	X	
Dr. A. van Houselt	Assist. prof.	TNW-PIN	X	X		X	X	B: M07: Introduction to Solid State Physics M: Modern Topics in Condensed Matter Physics
Prof.dr.ir. M. Huijben	Full prof.	TNW-IMS	X	X	X	X	X	M: AMM-Characterisation AMM-Inorganic Materials Science
Dr.ir. J.M. Huijser	Assoc. prof.	TNW-PCS						M: Molecular Structure and Spectroscopy
Dr. S.G. Huisman	Assist. prof.	TNW-POF	X	X		X	X	M: Advanced Fluid Mechanics Experimental Techniques in Physics of Fluids
Dr.ir. J.S. Kanger	Lecturer	TNW-AP		X		X	X	B: M01: Programming and Data Analysis 1 M02: Programming and Data Analysis 2 M04: Geometrical Optics M06: Module coordinator M06: Optics M: Machine Learning (also B-TN M11 elective)
Dr.ir. A.U. Kario	Assist. prof.	TNW-EMS	X	X		X	X	B: M03: Instrumentation M: Applications of Superconductivity
Prof.dr.ir. H.H.J. ten Kate	Full prof.	TNW-EMS	X	X	X	X	X	M: Applications of Superconductivity Cryogenic Science and Technology
Prof.dr. P.J. Kelly	Full prof.	TNW-CMS	X	X	X	X	X	M: Applied Quantum Mechanics Electronic Structure Theory I Theoretical Solid State Physics
Dr. J.A. Klärs	Assist. prof.	TNW-COPS	X	X		X	X	M: Nanophotonics Nanophotonic Experiments Quantum Emitters
Prof.dr. A. Kocer	Full prof.	TNW-BioEE						M: Physical Biology

Name	Position	Affiliation	BSc assign. Chair	BSc assign. Ref. member	MSc Assign. Chair	MSc Assign. Ref. member	Internship supervisor	Courses Applied Physics
Dr. E.S. Kooij	Assoc. prof.	TNW-PIN	X	X		X	X	B: M01: Dynamics and Relativity M07: Module coordinator M07: Introduction to Solid State Physics M11: Preparation Bachelor Assignment M: Modern Topics in Condensed Matter Physics
Prof.dr.ir. C.L. de Korte	Part-time prof.	TNW-POF	X		X			M: Medical Acoustics
Prof.dr.ir. G. Koster	Full prof.	TNW-IMS	X	X	X	X	X	M: AMM-Inorganic Materials Science
Dr. D.J. Krug	Assist. prof.	TNW-POF	X	X		X	X	M: Experimental Techniques in Physics of Fluids Heat and Mass Transfer
Dr.ir. R.W.E. van der Kruijs	Assist. prof.	TNW-XUV	X	X		X	X	
Prof.dr. A. Lagendijk	Full prof.	TNW-COPS	X	X	X	X	X	M: Nanophotonics
Dr. G.P.R. Lajoinie	Assist. prof.	TNW-POF	X	X		X	X	M: Medical Acoustics
Prof.dr. S.J.G. Lemay	Full prof.	TNW-BE	X	X	X	X	X	B: M04: Engineering Systems M05: Signals M: Soft Matter Physics (also B-TN M11 elective) Ions and Devices
Dr. L. Leppert	Assist. prof.	TNW-CCP	X	X		X	X	
Dr. C. Li	Assist. prof.	TNW-ICE	X	X		X	X	B: M04: Quantum Matter M: Nanophysics
Prof.dr. D. Lohse	Full prof.	TNW-POF	X	X	X	X	X	
Prof.dr. S. Luding	Full prof.	ET-MSM						M: Granular Matter
Dr. C. Maaß	Assoc. prof.	TNW-POF	X	X		X	X	
Dr.ir. I. Makhotkin	Assist. prof.	TNW-XUV	X	X		X	X	
Dr. A. Marin	Assoc. prof.	TNW-POF	X	X		X	X	B: M01: Project Dynamics and Relativity M: Experimental Techniques in Physics of Fluids
Prof.dr.ir. D.A.I. Marpaung	Adjunct prof.	TNW-LPNO	X	X	X	X	X	B: M03: Electromagnetics M: Experimental Laser Physics and Nonlinear Optics Small Signals and Detection
Prof.dr. R.M. van der Meer	Full prof.	TNW-POF	X	X	X	X	X	B: M08: Module coordinator M08: Fluid Physics M: Granular Matter
Dr. M. Morales Masis	Assoc. prof.	TNW-IMS	X	X		X	X	
Prof.dr. F. Mugele	Full prof.	TNW-PCF	X	X	X	X	X	B: M07: Statistical Physics M: Capillarity Phenomena Soft Matter Physics (also B-TN M11 elective)
Dr.ing. A. Nijhuis	Researcher	TNW-EMS	X	X		X	X	
Prof.dr.ir. H.L. Offerhaus	Full prof.	TNW-OS	X	X	X	X	X	B: M03: Module coordinator M03: Electromagnetics M: Ethical and Cultural Awareness Experimental Laser Physics and Nonlinear Optics Nano-optics
Dr. C. Otto	Assoc. prof.	TNW-MCBP						M: Biophysical Techniques and Molecular Imaging
Dr. L. Pehlivan	Lecturer	EEMCS-MOR						B: M01: Calculus 1
Prof.dr. P.W.H. Pinkse	Full prof.	TNW-AQO	X	X	X	X	X	B: M04: Geometrical Optics M11: Technical Optics M: Quantum Optics
Dr. J.W. Polderman	Assoc. prof.	EEMCS-HS						B: M02: Calculus 2
Prof.dr. A. Prosperetti	Part-time prof.	TNW-POF	X		X			
Dr. A.H.M.E. Reinders	Assoc. prof.	ET-DE						M: Solar Energy
Dr. J.J. Renema	Assist. prof.	TNW-AQO	X	X		X	X	M: Quantum Optics
Prof.dr.ing. A.J.H.M. Rijnders	Full prof.	TNW-IMS	X	X	X	X	X	
Dr. R. Saive	Assist. prof.	TNW-IMS	X	X		X	X	B: M06: Optics M: Solar Energy Wave Optics
Dr. J.P. Schilder	Assist. prof.	ET-AM						B: M05: Engineering Solid Mechanics
Dr. G.M.J. Segers-Nolten	Assist. prof.	TNW-NBP	X	X		X	X	
Ing. M.H. Siekman	Technician	TNW-PIN						M: Small Signals and Detection
Dr. I. Sîretanu	Assist. prof.	TNW-PCF	X	X		X	X	M: AMM-Characterisation Nano-fluidics
Dr. P.J.M. van der Slot	Researcher	TNW-LPNO	X	X		X	X	B: M06: Optics M: Laser Physics Nonlinear Optics Wave Optics

Name	Position	Affiliation	BSc assign. Chair	BSc assign. Ref. member	MSc Assign. Chair	MSc Assign. Ref. member	Internship supervisor	Courses Applied Physics
Prof.dr. J.H. Snoeijer	Full prof.	TNW-POF	X	X	X	X	X	B: M03: Module coordinator M03: Dynamics and Relativity M: Fluids and Elasticity Mathematical and Numerical Physics
Dr. K. Sotthewes	Researcher	TNW-PIN	X	X		X	X	M: Modern Topics in Condensed Matter Physics
Prof.dr.ir. W. Steenbergen	Full prof.	TNW-BMPI	X	X	X	X	X	M: Biomedical Optics
Dr. R.J.A.M. Stevens	Assist. prof.	TNW-POF	X	X		X	X	M: Mathematical and Numerical Physics Turbulence
Dr.ir. J.M. Sturm	Assist. prof.	TNW-XUV	X	X		X	X	B: M06: Optics M: Surfaces and Thin Layers
Dr. S. Vanapalli	Assoc. prof.	TNW-EMS						B: M02: Thermodynamics M: Cryogenic Science and Technology Heat and Mass Transfer
Prof.dr. J.J.W. van der Vegt	Full prof.	EEMCS-MACS						B: M03: Vector Calculus
Ir. I.C.W.T.A. van Veldhoven	Lecturer	TNW-AP						B: M01: Laboratory Practice 1 M02: Laboratory Practice 2 M02: Thermodynamics M02: Project Thermodynamics M03: Instrumentation M04: Engineering Systems M05: Models
Prof.dr.ir. I.M. Vellekoop	Full prof.	TNW-BMPI	X	X	X	X	X	B: M03: Optics M: Biomedical Optics
Dr. J.W.J. Verschuur	Lecturer	TNW-AP		X		X	X	B: M03: Analytical Programming M04: Engineering Systems M05: Signals M05: Models M05: Project Systems M06: Quantum Mechanics M08: Electrodynamics M: Applied Quantum Mechanics Computational Physics (also B-TN M11 elective) Remote Control of Experiments (also B-TN M11 elective) Small Signals and Detection
Prof.dr. M. Versluis	Full prof.	TNW-POF	X	X	X	X	X	B: M08: Fluid Physics M: Medical Acoustics Physics of Bubbles
Prof.dr. R. Verzicco	Part-time prof.	TNW-POF	X		X			
Prof.dr. W.L. Vos	Full prof.	TNW-COPS	X	X	X	X	X	M: Nanophotonics Nanophotonic Experiments Quantum Emitters
Dr.ir. G.C. Vreman-de Olde	Education consultant	CELT						B: M05: Module coordinator
Dr. H.R. Vutukuri	Assist. prof.	TNW-NBP	X	X		X	X	M: Soft Matter Physics (also B-TN M11 elective)
Dr. J.A. Wood	Assist. prof.	TNW-SFI						B: M09: Advanced Colloids and Interfaces
Dr.ir. H. Wormeester	Assoc. prof.	TNW-PIN	X	X		X	X	B: M05: Models M05: Project Systems M: Modern Topics in Condensed Matter Physics Surfaces and Thin Layers
Dr. A. Yakshin	Assist. prof.	TNW-XUV	X	X		X	X	
Prof.dr.ir.H.J.W. Zandvliet	Full prof.	TNW-PIN	X	X	X	X	X	B: M07: Introduction to Solid State Physics M: Nanophysics Modern Topics in Condensed Matter Physics Surfaces and Thin Layers
Prof. X. Zhang	Part-time prof.	TNW-POF	X		X			

APPENDIX 2.4. OVERVIEW OF THE QUALITY ASSURANCE SYSTEM

In figure A2.4.1 an overview is shown of the quality assurance as a part of the educational process, as it is implemented for the science and technology programmes within our faculty, including Applied Physics. The process can be influenced through adaptation of the conditional parameters such as the curriculum, quantity and quality of staff, student support & counselling, facilities and the information to prospective students. The educational process is shown in a layered way, reflecting the hierarchically levels with respect to organisation and objectives:

- ***Curriculum level*** – medium-term evaluation
  The programme aims to educate students who attain the intended learning outcomes under the condition that study duration and dropout rate remain within boundaries.

- ***Module (BSc) and course (MSc) level*** – short-term evaluation
  Every module or course contributes to the curriculum and it is evaluated regularly.

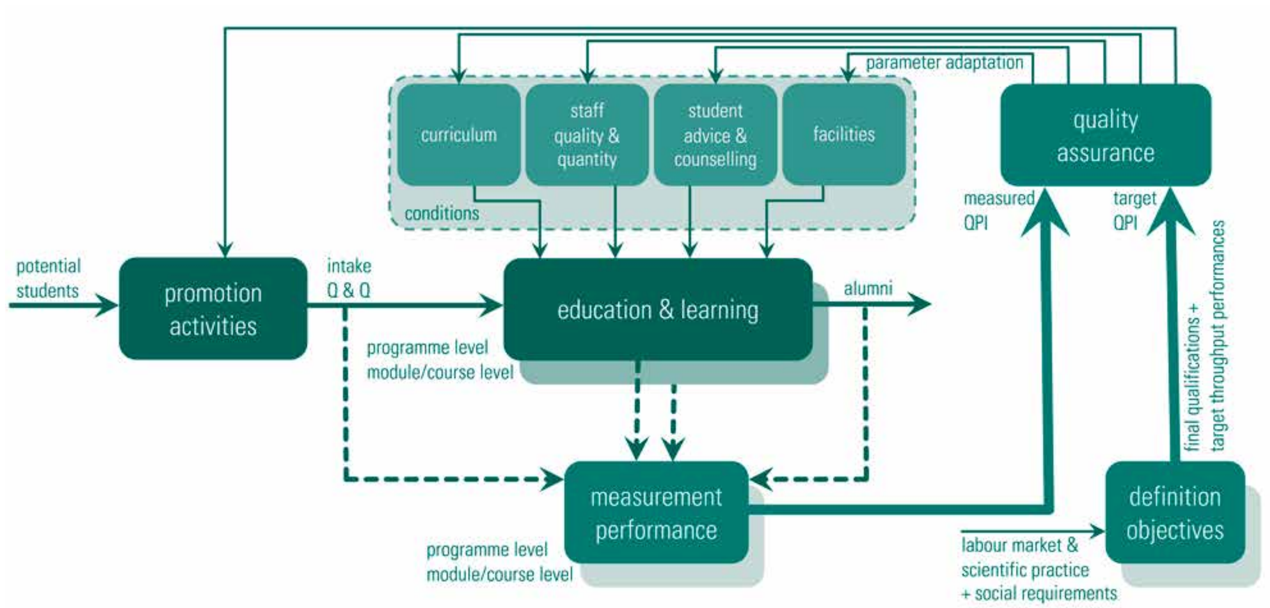


Figure A2.4.1 *Quality assurance within Applied Physics (QPI = quality performance indicator, Q&Q = quality and quantity).*

QUALITY ASSURANCE

Quality assurance has been implemented according to the PDCA-cycles: Plan, Do, Check, Act. The cycle or controls have been defined on the two aforementioned levels. Results of the evaluation activities are made available to students and lecturers through a canvas site dedicated to quality assurance. In addition, the programme staff and teachers inform students about improvements, also based on the quality assurance cycles.

MODULE / COURSE LEVEL – SHORT-TERM

On this level, there are slight differences between the bachelor's and master's programme, but the same instruments are used (surveys and panel meetings). For the bachelor's programme the quality assurance committee, the coordinator quality assurance and the programme coordinator take a central role in the module evaluation. They communicate with students, teachers and staff including the programme director, and prepare the module evaluation reports. The quality assurance committee consists of approximately 6 students and is chaired by the coordinator quality assurance. Four different control loops at module level are distinguished (see also figure A2.4.2):

Loop 0: **Direct communication between students and teachers**
The direct interaction between students and teachers is the basis for improvements in the learning process. Students are encouraged to provide feedback and discuss their experiences.

Loop 1: **Feedback via the quality assurance committee**
For every module, representatives from the student panel discuss their experiences with the lecturers in the lecturer panel meeting. The minutes of that meeting, together with all evaluation results of the module, are included in the module evaluation report. The report includes a description of the commitments by the lecturers for improvements.

Loop 2: **Feedback via the programme committee and programme staff**
The module evaluation report is sent to the programme committee and the programme staff. The programme committee advises about the points of attention. The programme staff keeps an eye on the points of attention. If necessary, the programme coordinator or programme director stays in touch with the lecturers.

Loop 3: **Feedback via the faculty management**
The faculty board uses several performance indicators as part of the job appraisals of the lecturers.

CURRICULUM LEVEL – MEDIUM-TERM

The programme director is responsible for the curriculum. Smaller changes in the curriculum, often to solve bottlenecks in modules or courses, are implemented by the programme staff after consultation with the chamber Applied Physics (all professors within the discipline) and following advice and/or approval from the programme committee. Further input is obtained from the NSE, the alumni survey and many discussions among students and staff. For more substantial changes, such as implementation of the TOM curriculum committee is consulted. After many years of inactivity, we recently re-installed a curriculum committee, to advise on a number of necessary issues in both the bachelor and master curricula.

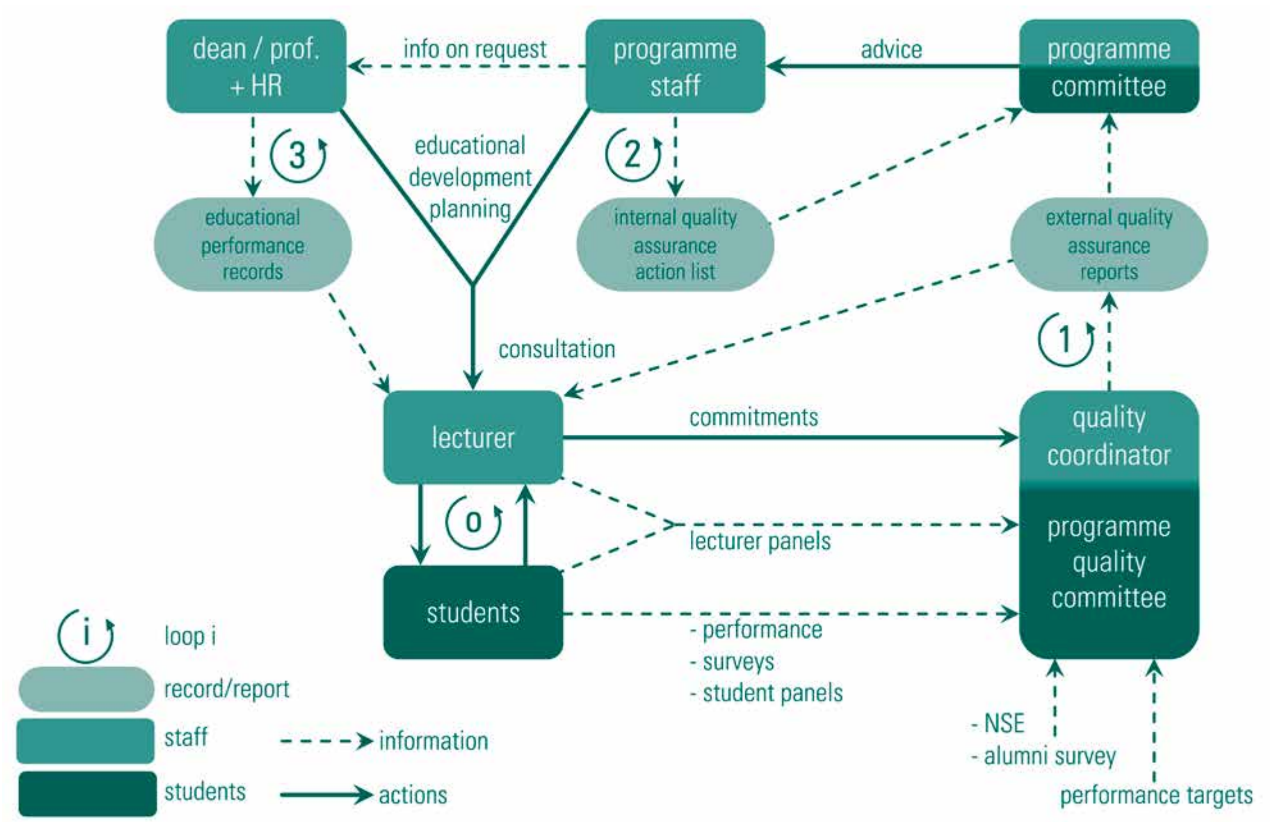


Figure A2.4.2 *Control loops in the module evaluations in the bachelor's programme.*

APPENDIX 3.1. OVERVIEW OF ASSESSMENT METHODS

Below we briefly describe the different forms of assessment used within Applied Physics. All methods can be applied individually or in a group.

Written exam: a traditional exam, which can be an open-book or closed-book exam. If the situation allows and/or requires, a written exam can also be taken remotely online. This form of testing enables the examiner to check if students have all required knowledge. Sometimes intermediate tests are used to already cover parts of the content.
Each written test should be viewed beforehand by at least two different lectures, i.e. the 4-eyes principle, including the examiner involved in the topic. Checks are made concerning the distribution, level and formulation (clear and unambiguous) of questions and whether there are follow-up questions, i.e. where an answer to a previous question is needed for a subsequent problem.

Oral exam/interview: a conversation in which the examiner has the possibility to ask content-related questions. Based on the answers to questions, the examiner may ask follow-up questions. Oral exams can be done with multiple assessors, and may be conducted remotely, i.e. via an online platform. If the oral exam is a major part of the grade of the study unit, a second person (lecturer or teaching assistant) must attend the examination to ensure the validity, reliability and transparency of the exam.

Presentation: students present their work by giving a (short) presentation. The examiner provides a clear instruction about what needs to be covered in the presentation. Presentations can be graded by multiple assessors; generally, rubrics are used to ensure the reliability of assessment.

Demonstration: students demonstrate a product of their work. Students are required to design and/or build a product with specified guidelines and restrictions. Demonstrations may be evaluated by multiple assessors; rubrics are used to ensure the reliability of assessment.

Assignment: students need to solve pre-defined problems. This enables the examiner to check if the student can apply the knowledge. For grading of assignments, rubrics should be drawn up before the assessment. If the assessment comprises a major part of the examination, it should be conducted by at least two persons.

Lab journal: a written report, in chronological order, of the performed lab work. Students can clarify steps that were taken to prepare for and perform the experiment. To ensure reliable grading, assessment criteria are discussed with the graders. To align grading, the graders jointly go through a number a lab journals.

Report/essay/paper: a written document describing the process, progress and results of technical or scientific work. It may also include recommendations and conclusions of the work.

Video/website: a visual presentation about the outcome of a given problem or assignment.

Contribution: assessment of the effort students have put into an activity. It is mostly combined with other assessment methods, such as writing a report or conducting an interview. The contribution can be assessed by examiners or by other students in the form of peer grading.

These assessment methods are most often used for summative assessment, i.e. to determine whether students meet the learning objectives of a study unit. However, formative assessment is also part of the didactic approach of the programme. This may be done by peer feedback among students, but also through (optional) homework assignments; these may give rise to bonus points in the final examination. Furthermore, during many educational activities, such as tutorials, lab courses or project activities, lectures and/or teaching assistants (senior students) are present to answer questions and provide feedback. We do not believe in one-way communication, in which we only provide resources (for example elaborate solutions). We encourage students to take on an active attitude toward their study by asking for the help they need. Within projects students are expected to contact project supervisors or experts themselves. Feedback on the learning process can also be asked for example by handing in draft versions of the report for an assignment; again, students should be in the lead.

APPENDIX 3.2. EXAMPLES OF ASSESSMENT PLANS

Toetsschema TN MOD01 Dynamica en Relativiteit (202000671), collegejaar 2020/2021
Assessment plan TN MOD01 Dynamics and Relativity (202000671), academic year 2020/2021

Modulecoördinator: prof. dr. J.H. Snoeijer
Module coordinator: prof. dr. J.H. Snoeijer

Onderwijseenheid *Study unit*	Cursuscode *Course code*	Examinator *Examiner*	Min. cijfer *Min. grade*	Taal *Language*	EC *EC*		Toets(en) *Test(s)*	Toetsvorm *Method of assessment*	Min. cijfer *Min. grade*	Weging (%) *Weight (%)*	Docent(en) *Lecturer(s)*
Dynamica en Relativiteit *Dynamics and Relativity*	20200672	Prof.dr. J.H. Snoeijer	6.0	NL	5	1	Translatie, rotatie en energie *Translation, rotation and energy*	Schriftelijke toets[1] *Written test[1]*		50%	J.H. Snoeijer,
						2	Trillingen, golven en speciale relativiteit *Vibrations, waves and special relativity*	Schriftelijke toets[1] *Written test[1]*		50%	J.H. Snoeijer, E.S. Kooij
Calculus 1 *Calculus 1*	202001215	Dr. L. Pehlivan	6.0	EN	4	1		Schriftelijke toets[1] *Written test[1]*		100%	L. Pehlivan
						2		TBL Sessies *TBL Sessions*	V/NVD *P/F*		
Experimenteren 1 *Laboratory Practice 1*	202000637	Ir. I.C.W.T.A. van Veldhoven	6.0	NL	1,5	1	Experimenten *Experiments*	Journaals *Lab journals*		100%	I.C.W.T.A. van Veldhoven
Programmeren en Dataverwerking 1 *Programming and Data Processing 1*	202000679	Dr.ir. J.S. Kanger	6.0	NL	2	1		Opdrachten *Assignments*		100%	J.S. Kanger
Project Dynamica en Relativiteit *Project Dynamics and R[…]*	202000675	Dr. A. Marin	6.0	EN	2.5	1	Deel 1: inleidende opdrachten *Part 1: introduction assignments*	Journaals *Lab journals*		30%	A. Marin, C.I. van Emmerik, I.C.W.T.A van Veldhoven
						2	Deel 2: eindopdracht *Part 2: final assignment*	Verslag en demonstratie *Report and demonstration*		60%	A. Marin
						3	Project vaardigheden *Project skills*	Evaluatiegesprek *Feedback meeting*		10%	A. Marin, C.I. van Emmerik

[…]nsing is te vinden in het rooster van de module, zie https://rooster.utwente.nl. Tenzij in Cavas anders beschreven is het niet
[…]dule of the module, see https://rooster.utwente.nl. Unless announced in Canvas registration for

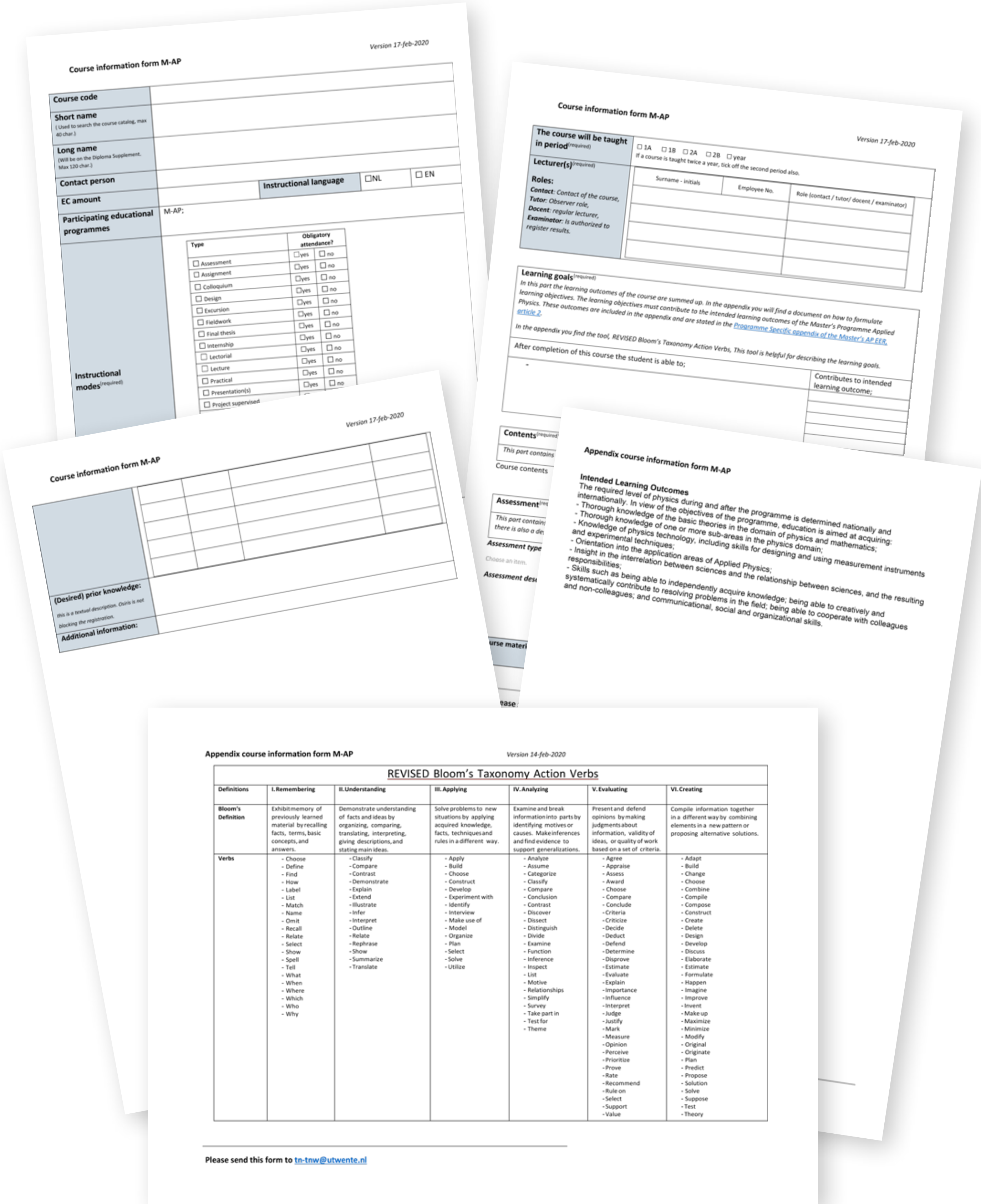
Toetsschema 202000696 TN MOD06 Golven, Interferentie en Waarschijnlijkheid , collegejaar 2020/2021
Assessment plan 202000696 TN MOD06 Waves, Interference and Probability, academic year 2020/2021

Modulecoördinator: Dr.ir. J.S. Kanger
Module coordinator: Dr.ir. J.S. Kanger

Onderwijseenheid *Study unit*	Cursuscode *Course code*	Examinator *Examiner*	Min. cijfer *Min. grade*	Taal *Language*	EC *EC*		Toetsomschrijving *Test descriptions*	Toetsvorm *Method of assessment*	Min. cijfer *Min. grade*	Weging (%) *Weight (%)*	Docent(en) *Lecturer(s)*
Optica *Optics*	202000697	Dr. R. Saive	6.0	EN	7	1	Theorie toets 1 [1,2] *Theory Test 1 [1,2]*	Schriftelijke toets *Written test*	5.0	35%	Dr. R. Saive, Dr. P.J.M. van der Slot, Dr.ir. J.M. Sturm, Dr.ir C.I. van Emmerik, Prof.dr.ir. I.M. Vellekoop, Dr.ir. J.S. Kanger
						2	Theorie toets 2 [1,2] *Theory Test 2 [1,2]*	Schriftelijke toets *Written test*		35%	
						3	Experimenten, presentatie en artikel[2] *Experiments, presentation and article[2]*	Practicum *Lab course*	5.0	30%	
Quantum-mechanica *Quantum Mechanics*	202000698	Prof.dr.ir. A. Brinkman	6.0	EN	6	1	Schriftelijke toets en huiswerkopgaven[1,3] *Written test and homework assignments[1,3]*	Schriftelijke toets[1] en opdrachten *Written test[1] and assignments*		100%	Prof.dr.ir. A. Brinkman, Dr. J.W.J. Verschuur
Hilbertruimte *Hilbert Space*	202000699	Dr. R.M.J. van Damme	6.0	EN	2	1		Schriftelijke toets[1] *Written test[1]*		100%	Dr. R.M.J. van Damme

[1] **De datum, tijd en locatie van een toets, collectieve toets inzage of herkansing is te vinden in het rooster van de module, zie https://rooster.utwente.nl. Tenzij in Cavas anders beschreven, is het niet nodig om in te schrijven op de toets of herkansing.**
[1] *The date and location of a test, collective result inspection or retake of a test can be found in the schedule of the module, see https://rooster.utwente.nl. Unless announced in Canvas registration for a test or retake is not necessary.*
[2] **Studenten die alleen het theoretische 4.5 EC deel van Optica volgen , nemen alleen deel aan de twee schriftelijke toetsen. De weging van de toetsen is 50% en het minimum slaagcijfer van Optics 4.5 EC is 5.5 (afgerond 6)**
[2] *Students who follow the 4.5 EC theoretical part of Optics, will only do the two written tests. The weight of both tests is 50%, the passing grade for the course Optics 4.5 EC is 5.5 (rounded to a 6)*
[3] **Het huiswerk voor Quantum Mechanica wordt beoordeeld. Het eindresultaat van het module-onderdeel wordt berekend via G = H+ E(10-H)/10 G is het module-onderdeel cijfer, H is het resultaat voor het huiswerk (maximaal 2 punten) en E is het resultaat van de toets (maximaal 10 punten).**
[3] The homework for Quantum Mechanics will be graded. The final grade for the submodule will be calculated via G = H+ E(10-H)/10 where G is the course grade, H is the grade for the homework (maximum 2 points) and E is the grade for the exam (maximum 10 points).

APPENDIX 3.3. STANDARD FORM COURSE INFORMATION



Course information form M-AP

Version 17-feb-2020

Course code			
Short name (Used to search the course catalog, max 40 char.)			
Long name (Will be on the Diploma Supplement. Max 120 char.)			
Contact person		Instructional language	☐NL ☐EN
EC amount			
Participating educational programmes	M-AP;		
Instructional modes(required)			

Type	Obligatory attendance?	
☐ Assessment	☐yes	☐ no
☐ Assignment	☐yes	☐ no
☐ Colloquium	☐yes	☐ no
☐ Design	☐yes	☐ no
☐ Excursion	☐yes	☐ no
☐ Fieldwork	☐yes	☐ no
☐ Final thesis	☐yes	☐ no
☐ Internship	☐yes	☐ no
☐ Lectorial	☐yes	☐ no
☐ Lecture	☐yes	☐ no
☐ Practical	☐yes	☐ no
☐ Presentation(s)	☐yes	☐ no
☐ Project supervised		

Course information form M-AP

Version 17-feb-2020

The course will be taught in period(required)	☐ 1A ☐ 1B ☐ 2A ☐ 2B ☐ year If a course is taught twice a year, tick off the second period also.
Lecturer(s)(required)	Surname - initials / Employee No. / Role (contact / tutor/ docent / examinator)
Roles: *Contact: Contact of the course,* *Tutor: Observer role,* *Docent: regular lecturer,* *Examinator: Is authorized to register results.*	

Learning goals(required)

In this part the learning outcomes of the course are summed up. In the appendix you will find a document on how to formulate learning objectives. The learning objectives must contribute to the intended learning outcomes of the Master's Programme Applied Physics. These outcomes are included in the appendix and are stated in the Programme Specific appendix of the Master's AP EER, article 2.

In the appendix you find the tool, REVISED Bloom's Taxonomy Action Verbs. This tool is helpful for describing the learning goals.

After completion of this course the student is able to:

	Contributes to intended learning outcome:
-	

Contents(required)

Assessment(required)

Course information form M-AP

Version 17-feb-2020

(Desired) prior knowledge:
this is a textual description. Osiris is not blocking the registration.

Additional information:

Appendix course information form M-AP

Intended Learning Outcomes

The required level of physics during and after the programme is determined nationally and internationally. In view of the objectives of the programme, education is aimed at acquiring:
- Thorough knowledge of the basic theories in the domain of physics and mathematics;
- Thorough knowledge of one or more sub-areas in the physics domain;
- Knowledge of physics technology, including skills for designing and using measurement instruments and experimental techniques;
- Orientation into the application areas of Applied Physics;
- Insight in the interrelation between sciences and the relationship between sciences, and the resulting responsibilities;
- Skills such as being able to independently acquire knowledge; being able to creatively and systematically contribute to resolving problems in the field; being able to cooperate with colleagues and non-colleagues; and communicational, social and organizational skills.

Appendix course information form M-AP

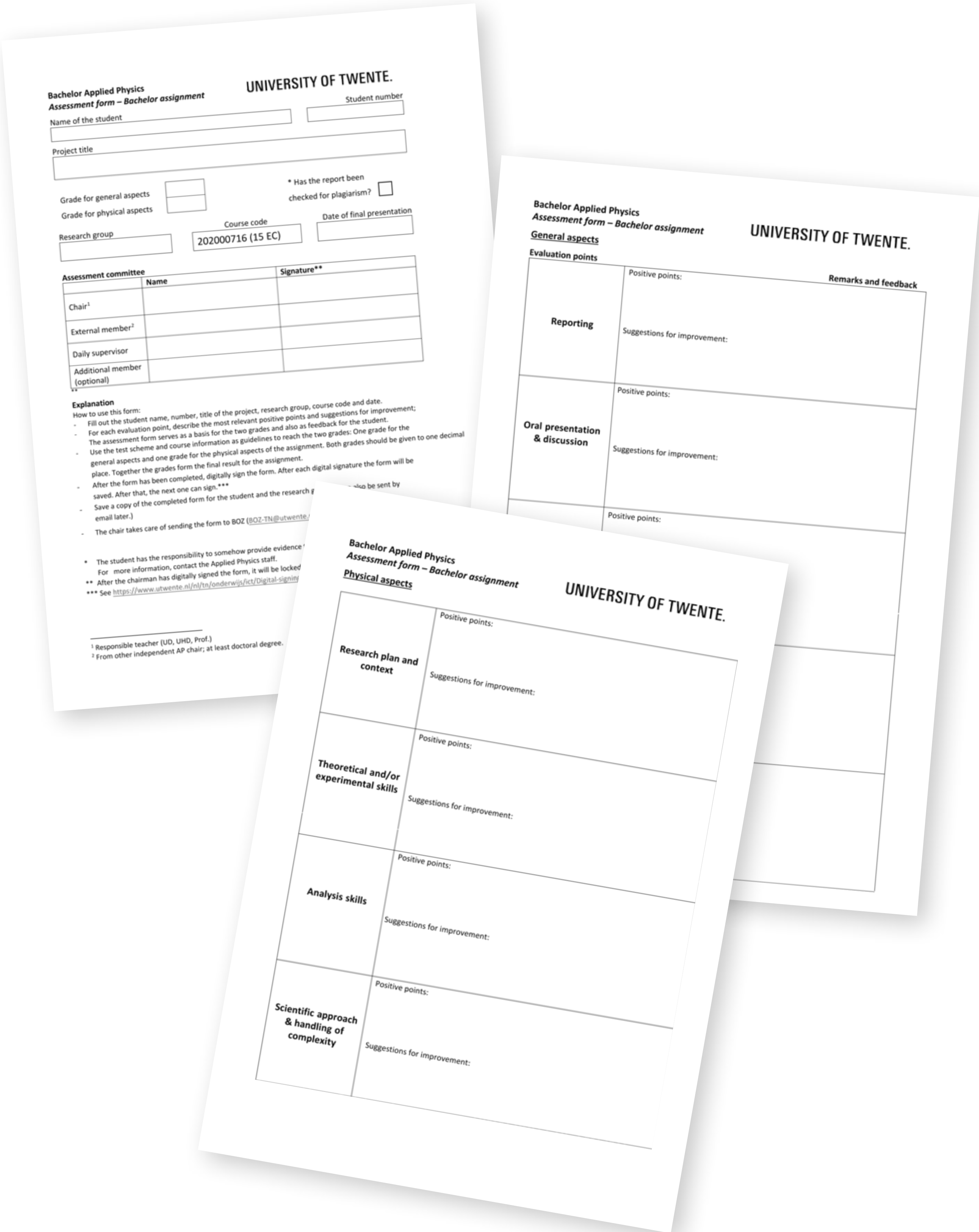
Version 14-feb-2020

REVISED Bloom's Taxonomy Action Verbs

Definitions	I. Remembering	II. Understanding	III. Applying	IV. Analyzing	V. Evaluating	VI. Creating
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.
Verbs	- Choose - Define - Find - How - Label - List - Match - Name - Omit - Recall - Relate - Select - Show - Spell - Tell - What - When - Where - Which - Who - Why	- Classify - Compare - Contrast - Demonstrate - Explain - Extend - Illustrate - Infer - Interpret - Outline - Relate - Rephrase - Show - Summarize - Translate	- Apply - Build - Choose - Construct - Develop - Experiment with - Identify - Interview - Make use of - Model - Organize - Plan - Select - Solve - Utilize	- Analyze - Assume - Categorize - Classify - Compare - Conclusion - Contrast - Discover - Dissect - Distinguish - Divide - Examine - Function - Inference - Inspect - List - Motive - Relationships - Simplify - Survey - Take part in - Test for - Theme	- Agree - Appraise - Assess - Award - Choose - Compare - Conclude - Criteria - Criticize - Decide - Deduct - Defend - Determine - Disprove - Estimate - Evaluate - Explain - Importance - Influence - Interpret - Judge - Justify - Mark - Measure - Opinion - Perceive - Prioritize - Prove - Rate - Recommend - Rule on - Select - Support - Value	- Adapt - Build - Change - Choose - Combine - Compile - Compose - Construct - Create - Delete - Design - Develop - Discuss - Elaborate - Estimate - Formulate - Happen - Imagine - Improve - Invent - Make up - Maximize - Minimize - Modify - Original - Originate - Plan - Predict - Propose - Solution - Solve - Suppose - Test - Theory

Please send this form to tn-tnw@utwente.nl

APPENDIX 3.4. STANDARD ASSESSMENT FORM - BACHELOR



Bachelor Applied Physics
Assessment form – Bachelor assignment

UNIVERSITY OF TWENTE.

Name of the student

Student number

Project title

Grade for general aspects

Grade for physical aspects

* Has the report been checked for plagiarism?

Research group

Course code
202000716 (15 EC)

Date of final presentation

Assessment committee

	Name	Signature**
Chair[1]		
External member[2]		
Daily supervisor		
Additional member (optional)		

Explanation
How to use this form:
- Fill out the student name, number, title of the project, research group, course code and date.
- For each evaluation point, describe the most relevant positive points and suggestions for improvement; The assessment form serves as a basis for the two grades and also as feedback for the student.
- Use the test scheme and course information as guidelines to reach the two grades: One grade for the general aspects and one grade for the physical aspects of the assignment. Both grades should be given to one decimal place. Together the grades form the final result for the assignment.
- After the form has been completed, digitally sign the form. After each digital signature the form will be saved. After that, the next one can sign.***
- Save a copy of the completed form for the student and the research g... also be sent by email later.)
- The chair takes care of sending the form to BOZ (BOZ-TN@utwente....

* The student has the responsibility to somehow provide evidence ... For more information, contact the Applied Physics staff.
** After the chairman has digitally signed the form, it will be locked...
*** See https://www.utwente.nl/nl/tn/onderwijs/ict/Digital-signing...

[1] Responsible teacher (UD, UHD, Prof.)
[2] From other independent AP chair; at least doctoral degree.

Bachelor Applied Physics
Assessment form – Bachelor assignment
General aspects

UNIVERSITY OF TWENTE.

Evaluation points

		Remarks and feedback
Reporting	Positive points:	
	Suggestions for improvement:	
Oral presentation & discussion	Positive points:	
	Suggestions for improvement:	
	Positive points:	

Bachelor Applied Physics
Assessment form – Bachelor assignment
Physical aspects

UNIVERSITY OF TWENTE.

Research plan and context	Positive points:
	Suggestions for improvement:
Theoretical and/or experimental skills	Positive points:
	Suggestions for improvement:
Analysis skills	Positive points:
	Suggestions for improvement:
Scientific approach & handling of complexity	Positive points:
	Suggestions for improvement:

Bachelor Applied Physics
Assessment form – Bachelor assignment

UNIVERSITY OF TWENTE.

Test scheme bachelor assignment

Module level		**Osiris level**			**Subject level**		
Topic	*min. grade*	*Subject*	*min. grade*	*Weight*	*Subject*	*Way of assessment*	*Weight*
Bachelor assignment	≥ 5,5	General aspects	≥ 5,5	50%	Learning objective 1	Progress meeting with supervisor(s)	10%
					Learning objective 2	Attitude during the assignment and meetings	20%
					Learning objective 3	Observation from the	10%
					Learning objective 4		
					Learning objective 5		
					Learning objective 6		
		Physical aspects	≥ 5,5	50%	Learning objective 7		
					Learning objective 8		

Bachelor Applied Physics
Assessment form – Bachelor assignment

UNIVERSITY OF TWENTE.

Course information

Course description

The Bachelor programme in Applied Physics ends with the Bachelor assignment. This allows the student to apply the knowledge and skills gained from experiments, use of theoretical models, data analysis and oral and written presentations throughout the entire Bachelor degree to a real area of research.

The student is responsible for contacting a research group and designing the project description (the research group will help with the latter). Before the start of the project, the project description and names of the assessment committee must be submitted to the secretary of the exam committee for review (via the programme coordinator).

The Bachelor assignment lasts 10 weeks full time (longer in the case of part-time research) and is based in the research group of the Chair. A daily supervisor (tutor) and teacher are assigned to assist in the smooth running.

Course content

The Bachelor assignment begins with an introduction and literature review. Then, the student must design an appropriate research plan and schedule that, with appropriate supervision, will allow him/her to address the research question.

The proposed research must contain sufficient scope and complexity to satisfy the requirements of a Bachelor assignment. It usually fits within the framework of ongoing scientific research of the host Chair. Throughout the project, the student discusses progress with the supervisor and teacher and adjusts the future direction as appropriate.

The Bachelor assignment ends with a written report and oral presentation, at the level expected of B3-students of Applied Physics. Assessment is done by the tutor, teacher, and an external committee member. The external committee member and teacher must both hold PhDs and be independent researchers (e.g., academic staff), coming from two different Chairs within Applied Physics (The tutor/daily supervisor is exempt from these requirements

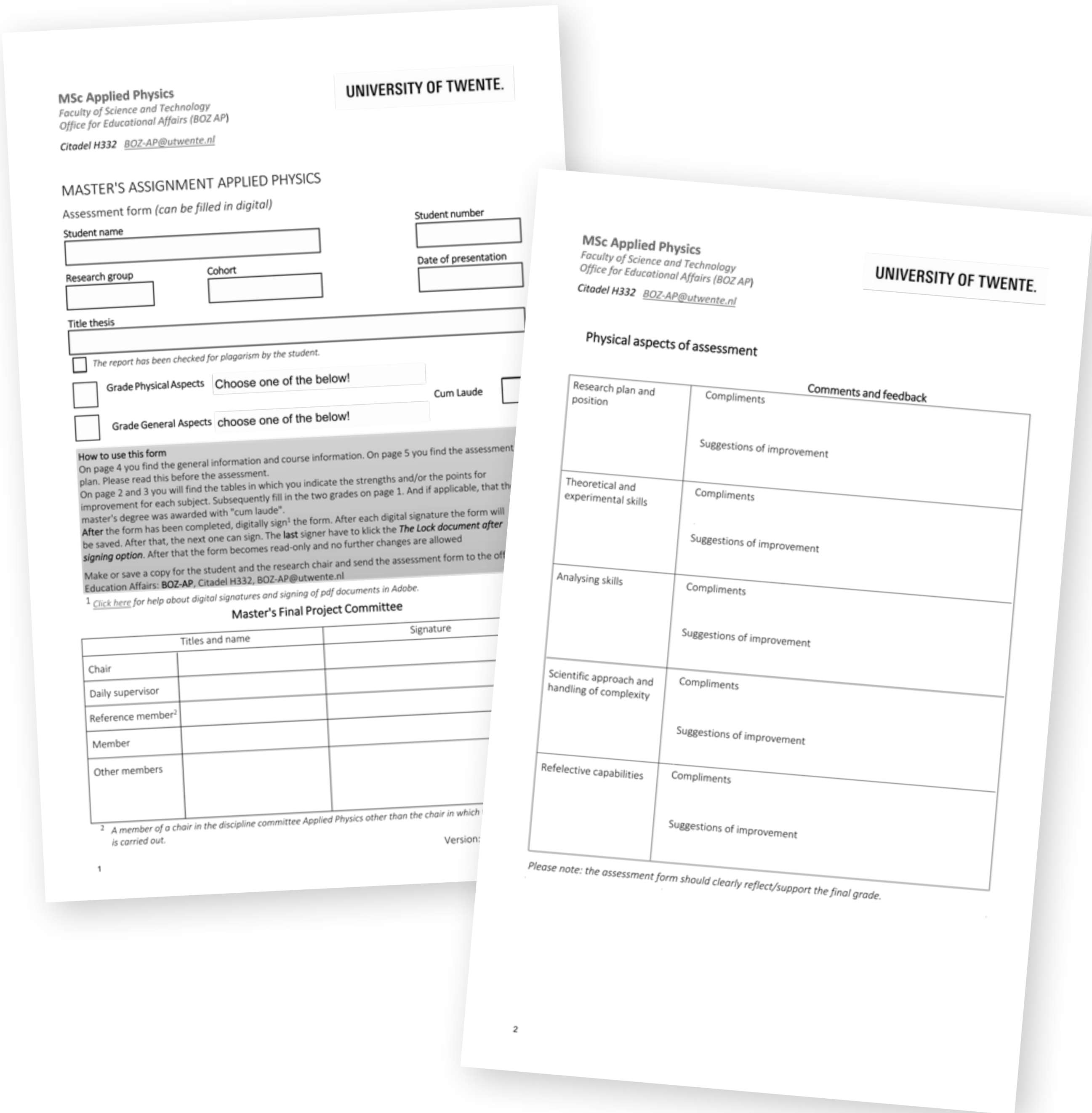
Bachelor Applied Physics
Assessment form – Bachelor assignment

UNIVERSITY OF TWENTE.

Learning objectives After finishing the bachelor assignment, the student is able to:	**Way of assessment**	**Weight**
1. Organise and plan a research project, from problem analysis to inclusion of feedback.	Progress meeting with supervisor(s)	5%
2. Demonstrate independence in the preparation and implementation of a research project, including use of critical scientific thinking.	Attitude during the assignment and meetings	10%
3. Function professionally, in terms of communication with other students and teachers, as well as collaborate within the research community (including beyond Applied Physics).	Observation from the supervisor(s)	5%
4. Provide a clear, structured, content-based, written report.	Report	15%
5. Orally present his/her research, through a clear, structured, content-based presentation, including discussion and questions/answers with a scientific audience (other students, graders, etc).	Presentation and discussion	10%
6. Place his/her research in a social context, as well as take into account safety, environmental, and ethical issues.	Context in report and presentation	5%
7. Gather, select and process relevant scientific information with the use of concept and theories from the relevant field, including state of the art.	Context in report and presentation	10%
8. Conduct Applied Physics research at the level expected of a final year Bachelor student, including using a systematic/logical approach to: Problem analysis, formulation of research question, theoretical and/or experimental methods, data collection, and analysis (including computation where necessary); and to be able to explain, with reasoning, why these approaches have been chosen.	Observation supervisor(s); report; presentation	40%

Learning objectives 1 to 6 determine the general aspects (=50%); learning objectives 7 and 8 determine the physical aspects of the assignment (=50%).

APPENDIX 3.5. STANDARD ASSESSMENT FORM - MASTER



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MASTER'S ASSIGNMENT APPLIED PHYSICS

Assessment form *(can be filled in digital)*

Student name
Student number
Research group
Cohort
Date of presentation
Title thesis

The report has been checked for plagiarism by the student.

Grade Physical Aspects — Choose one of the below!
Cum Laude
Grade General Aspects — choose one of the below!

How to use this form
On page 4 you find the general information and course information. On page 5 you find the assessment plan. Please read this before the assessment.
On page 2 and 3 you will find the tables in which you indicate the strengths and/or the points for improvement for each subject. Subsequently fill in the two grades on page 1. And if applicable, that the master's degree was awarded with "cum laude".
After the form has been completed, digitally sign[1] the form. After each digital signature the form will be saved. After that, the next one can sign. The **last** signer have to klick the ***The Lock document after signing option***. After that the form becomes read-only and no further changes are allowed

Make or save a copy for the student and the research chair and send the assessment form to the off
Education Affairs: **BOZ-AP**, Citadel H332, BOZ-AP@utwente.nl

1 *Click here for help about digital signatures and signing of pdf documents in Adobe.*

Master's Final Project Committee

	Titles and name	Signature
Chair		
Daily supervisor		
Reference member[2]		
Member		
Other members		

2 *A member of a chair in the discipline committee Applied Physics other than the chair in which is carried out.*

Version:

1

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Physical aspects of assessment

	Comments and feedback
Research plan and position	Compliments Suggestions of improvement
Theoretical and experimental skills	Compliments Suggestions of improvement
Analysing skills	Compliments Suggestions of improvement
Scientific approach and handling of complexity	Compliments Suggestions of improvement
Refelective capabilities	Compliments Suggestions of improvement

Please note: the assessment form should clearly reflect/support the final grade.

2

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General aspects of assessment

	Comments and feedback
Reporting	Compliments Suggestions of improvement
Oral presentation and discussion	Compliments Suggestions of improvement
Professional research attitude	Compliments Suggestions of improvement
Professional communication	Compliments Suggestions of improvement
Arrangement of own work within conditions of research group	Compliments Suggestions of improvement

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General information

Course code :	- Physical Aspects: 193599039 (25 EC) 201800344 (20 EC) - General Aspects: 193599089 (25 EC) 201800345 (20 EC)
Course name:	Master's Assignment: Applied Physics
Lecturers (chair of the MFPC is examiner/coordinator):	The MSc Final Project Committee (MFPC) is responsible for the supervision and assessment. The committee consists of a minimum of three members, that all have a doctors degree. The chair of the committee is the graduation professor, and at least one of the members should be from another research group within the Applied Physics domain of the faculty of Science and Technology (reference member). In case the graduation professor/chair is not from within the Applied Physics domain, the reference member should be a professor from the Applied Physics domain. For the guide lines see the Rules of the Board of examiners AP
Determining pass mark	In the assessment of the MSc assignment, two marks will be determined: (i) (grade covers the quality of the physical aspects and the research performan (ii) One grade covers the other objectives, concerning the oral and written reporting as well as other general aspects of the research. For each mark a distinct course code has been assigned. The assignment c be finalized when both grades are six (6) or higher.

Course Description
The individual MSc assignment comprises the completion of the master program Applied Physics. The objective of the assignment is that the student learns and proves that (s)he is able to define, perfor and reflect on a research project in the applied physics domain with a large degree of independenc The assignment is performed in one of the research groups within the Applied Physics domain of t Science and Technology of the University of Twente under the supervision of a researcher with a degree and the responsibility of a MSc Graduation Committee.
The assignment can be performed (partially) within a research group outside the domain of App an external institute or organization. This needs the approval of the master examination comm Physics.

Course Content
The student has to perform a substantial research or design project that meets scientific crit profundity and complexity is defined by the chair of the MSc graduation committee. The st the assignment with a written report (the MSc thesis) and an oral public presentation.
Students of cohort 2018 and higher graduate with a master's assignment of (2x20) 40 EC.
Students up to cohort 2018 graduate with a master's assignment of (2x25) 50 EC.

Programme objectives
In the master assignment, the programme's objectives are met, with focuses on acquiring most of the learning outcomes of the complete program:

- a thorough knowledge of the basic physics and mathematics theories;
- knowledge of physical technology, including skill in designing and applying measuring equipment and experimental techniques;
- orientation in the application areas of applied physics;
- insight into how the sciences are interconnected and the relation between science and society and the resulting responsibilities;
- skills such as being able to acquire knowledge independently; being able to contribute creatively and systematically to solving issues relating to the subject area; being able to work with colleagues;
- in and outside the discipline; and communicative, social and organizational skills.

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UNIVERSITY OF TWENTE.

Assessment plan Physics Research aspects

Learning objectives After following the course, the student is able to perform complex scientific research at a master level in the field of Applied Physics, and:	Assessment	Weight
1a. Is able to formulate an interpretation a research problem and to define the research goals 1b. Is able to define the theoretical and experimental research plan and position the research in the field.	Meeting MGC Report & presentation	~10%
2. Has the theoretical and experimental skills to execute the research, works systematically and makes well founded choices. Is able to recognize flaws in theory and has the skills to acquire missing parts.	Observation by supervisor Report & Presentation	~30%
3. Is able to analyse the results, draw conclusions and to reflect on the results with respect to the problem definition and research goals.	Observation by supervisor Report & Presentation	~30%
4. Has a scientific approach and possesses intellectual skills (can handle complexity)	Observation by supervisor Report	~20%
5. Is able to reflect on the contextual aspects of the research (social context, safety and environmental consequences, scientific and ethical aspects)	Report, Meeting MFPC Publication	~10%

Assessment plan Reporting & General aspects

Learning objectives After following the course, the student is able:	Assessment	Level	Weight
1. Is able to report adequately about the research in English. (report is well structured in clear and correct language)	Report	Report sufficient contents for publication	~25%
2. Is able to present and to discuss adequately about the research in English (presentation is well structured, with a clear explanation, supported by tools)	Presentation	Presentation for staff research	~25%
3. Is able to work with a high degree of independence, creativity, dedication, pace, commitment (the student himself is responsible for the progress, planning and	Observation by supervisor and MGC	Professional attitude	~20%
4. Is able to communicate professionally with the supervisor (problem owner), to co-operate with the members of the research group and to communicate with others from inside and outside the community of Applied Physics.	Observation by supervisor and MGC members		~15%
5. Is able to arrange his research within the conditions set by the group.	Observation by supervisor		~15%

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APPENDIX 4.1. SUMMARY ALUMNI SURVEY

To probe the opinion of our alumni on how they look back on their study time at the University of Twente, within the Applied Physics programme, we conducted an online survey in November and December 2020 among all alumni who graduated between 2010 and 2020. We received 71 responses, giving us a representative overview of many aspects of our programme. A summary of the most relevant results is provided below in table A4.1.1. The full results of the entire survey are available in the supplemental information. In addition, below the table, we include some characteristic and relevant remarks made by our alumni on the various aspects of the programme.

Table A4.1.1 *Quantitative results of the alumni survey on various aspects.*

Content of the programme	too little	bit too little	optimal score	bit too much	too much
Width of the programme	0%	13%	69.9%	17.4%	0%
Depth of the programme	1.4%	12.9%	75.7%	8.6%	1.4%
Balance between theory and practice	1.5%	7.4%	60.3%	27.9%	2.9%
Cohesion between different parts	0%	4.4%	70.6%	25%	0%
Quality of the programme	**very poor**	**poor**	**neutral**	**good**	**excellent**
Match to scientific theories and research	0%	0%	3%	51.5%	45.4%
Acquiring research skills	0%	0%	1.4%	47.9%	50.8%
Acquiring design skills	3%	7.5%	40.3%	47.7%	1.5%
Acquiring project skills	0%	3.3%	20.2%	58%	17.4%
Opinion about Applied Physics education	**very dissatisfied**	**dissatisfied**	**neutral**	**satisfied**	**very satisfied**
General satisfaction	0%	0%	0%	44.1%	55.9%
Acquired general skills	0%	4.3%	7.2%	46.4%	42%
Acquired academic skills	0%	0%	2.9%	58.6%	38.6%
Extent to which master's constitutes a good starting point	**not at all**	**small extent**	**neutral**	**large extent**	**very large extent**
to enter the job market	0%	0%	20.9%	46.5%	30.2%
for further development	0%	2.1%	4.3%	51.1%	42.6%

Are there any positives about the Applied Physics programme you would like to highlight or add?

"Good critical thinking and analytical skills after the programme."

"The entire staff and programme was excellent overall, I am very grateful to have studied physics at the UT and it helps me a lot during my work, even though I ended up working outside of Physics."

"I liked the fact that doing an internship abroad was strongly encouraged and supported."

"I think the broadness during the beginning of the bachelor's along with the flexibility to tune the programme later on and in the master's is very good. You can quite early identify where your interests lie and develop yourself in that direction accordingly."

"The Applied Physics programme is a very demanding programme. I have noticed around my colleagues with backgrounds in econometrics, actuarial science, mathematics and other technical master programmes that the Applied Physics degree gives a sort of status that you have proven to be smart. My current boss and also my previous one were impressed by my cum laude graduation when I applied for the position."

"Definitely the personal atmosphere and the accessibility of all professors. I'm not sure if you can find such a personal environment anywhere else."

Are there things you missed during your studies?

"As mentioned, an option to gear your master's more towards a career at a company instead of a purely scientific career."

"Insight in working practice outside academia (in addition to the internship)."

"Maybe a course focussing on writing of papers, academic publications (or let students write this more often for a project/ practical)."

"The aforementioned social skills. Also I had a last-semester-crush on biophysics, which was absolutely fantastic. Wish I had known of it sooner! (maybe that has already changed since 2014)."

"Practical non-academic assignments from industry."

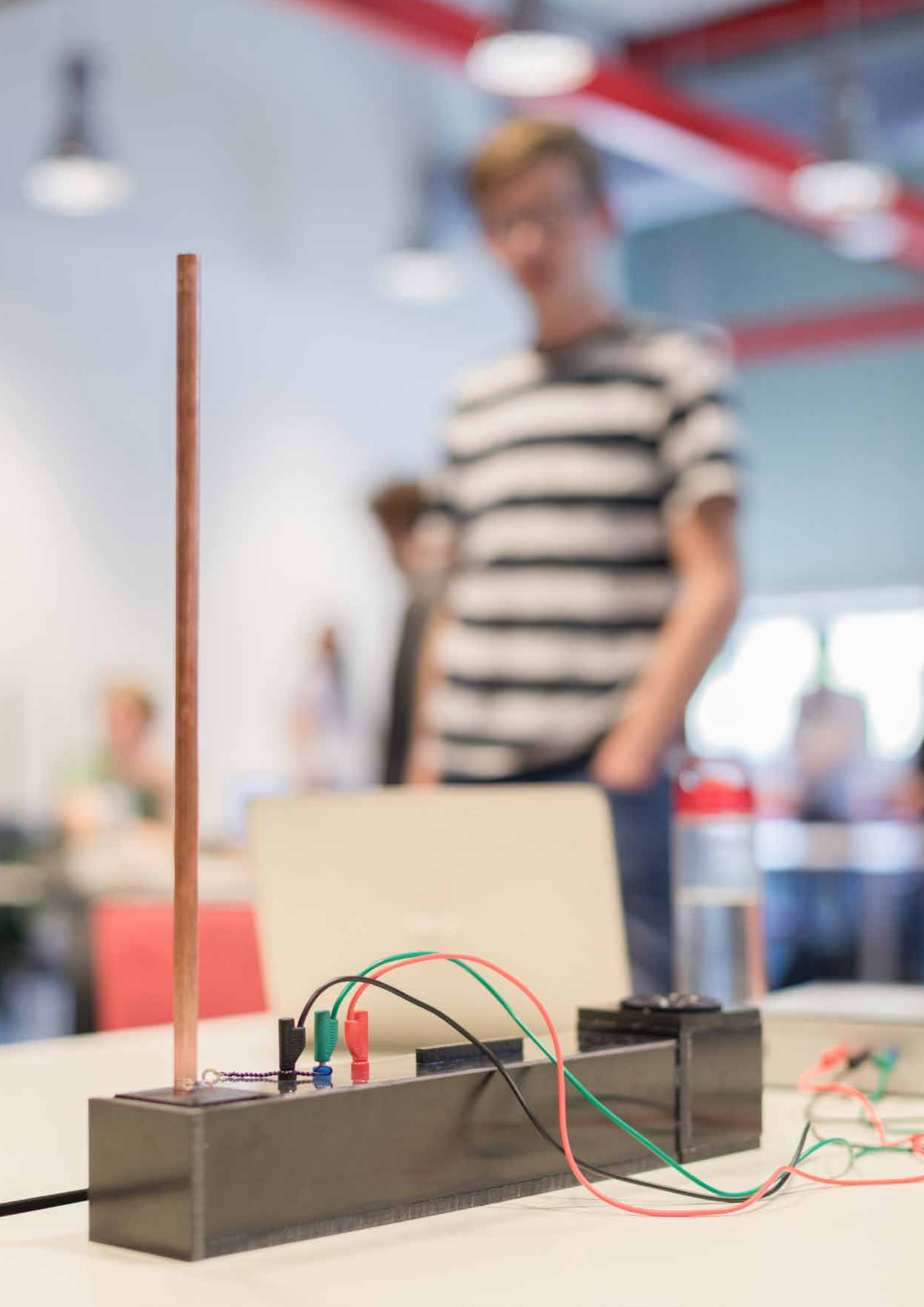
Do you have any final remarks or suggestions?

"I loved my studies at UT, and apart from the few points I mentioned, I'm very happy with my choice!"

"Keep the programme as strong as it has been. I've encountered people who graduated 20 years ago who still benefit from the skills gained."

"Stay Dutch, you'll learn English on the way."

"Thanks a lot for everything and I wish nothing but the best for the Applied Physics programme. I'm proud to be an alumnus!"



APPENDIX 4.2. CONTACTS WITH THE PROFESSIONAL FIELD

UNIVERSITY OF TWENTE SPIN-OFF AND START-UP COMPANIES

Many innovations of the University of Twente are brought on the market by over 1,000 spin-off and start-up companies. In the initial phase they are facilitated by the university and Kennispark Twente. In addition, NovelT and Incubase are there to help students transform their ideas into start-ups. Many of the start-up companies are in the field of (applied) physics and nanotechnology, and still have close relations with the university. Examples include Demcon, LioniX, Solmates, TSST, Medspray and Micronit Microfluidics.

INTERNSHIP COMPANIES

In their second year, Applied Physics master students do an internship, to experience future employment options. As described in chapter 4, approximately 35% of the students choose to join a company, most often in The Netherlands. Between 2013 and 2020, the internships were facilitated by the following companies (see also figure A4.2.1):

ASML	Deltares	LioniX BV
Abengoa	Demcon	Malvern Panalytical
Alliander N.V.	Demcon Kryoz	Marin
AMS	ETC Solar	Medspray BV
Apollo Tyres Global R&D	Focal Vision & Optics	Micronit Microfluidics
Bosch Global	IBM	Nanophoton Corporation
Bosch Thermotechnology	IBM Research	NieuweStroom
Coherent	Lambert Instruments	Oce-Technologies
Optics11	Rheem	Thales
Philips Research	See Cubic BV	Tide Microfluidics
Qmicro	Solmates	TSST – Twente Solid State Technology
Reden	Spectra Physics	VPIphotonics

Figure A4.2.1 *Overview of companies where our students do their internship, represented in a word cloud.*

FIRST JOB

Our alumni find work all across the globe and in many different sectors, ranging from academia to corporate businesses. Below we list the companies and organisations where our alumni (2013-2020) found their first job (see also figure A4.2.2).

Aalto University
ADLINK
Alliander
APE
ARNCL
ASML
Avante Consultancy
BDR Thermea Group
CE Delft
CERN
CRATR
Datawell
De Rozenhof
Deepsky Corp. Ltd.
Defensie
Deloitte
DEMCON
DeSiCi
EFPL
ETH Zürich
First Consulting
Hello Tomorrow
HZDR
IBM
Imec
Immend
King's College London
KIT
KPMG
KPN
LeydenJar Technologies
Linköping University

Adviesbureau de Haan
Adyen
MAch8lasers
MASER Engineering
Max Planck Institute
McKinsey&Company
Micronit
Movares
NanoNextNL
Nedap
Nikhef
NLR
NTNU Trondheim
NTS-Group
Oce Technologies
Philips
Phoenix Software
Profitero
QuiX BV
QuTech
Rabobank
Radboud Universiteit
RUG
SafanDarley
Salland Engineering
Sobolt
Solmates
Strategy Development Partners
StyduTree (parttime)
Tata Steel
Tecnotion
TenneT

AE&C
Alfen B.V.
Thales
TMC Physics
TNO
Topicus
Trymax Semiconductor
TU Delft
TU Dortmund
TU Dresden
TU/e
Twenco
UMC Utrecht
Université de Strasbourg
Universiteit Gent
Universiteit Leiden
Universiteit Utrecht
University of Cambridge
University of Copenhagen
University of Stuttgart
University of Valencia
University of Warwick
University of Zürich ((UZH)
University of Twente
University of Amsterdam (UvA)
VDL
VMI
VODW
VyCAP
Wetsus
Whayle
Witteveen + Bos

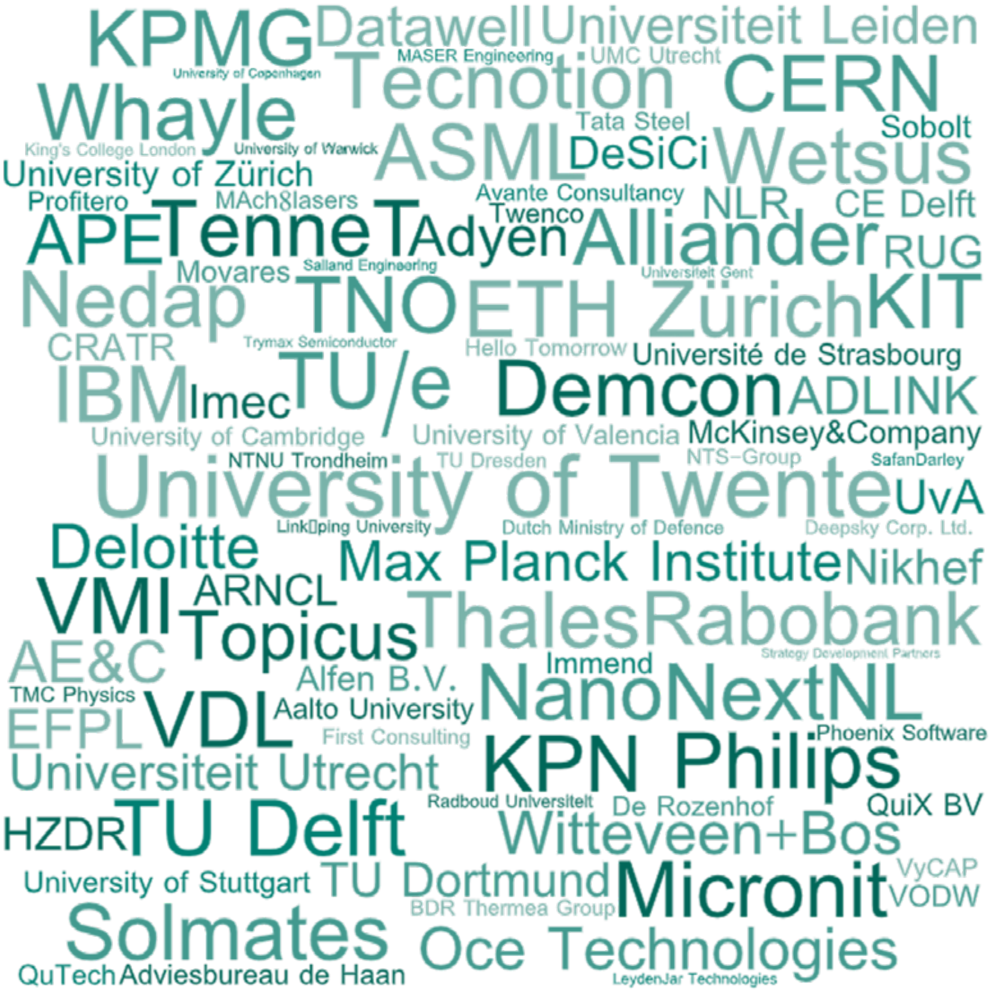


Figure A4.2.2 *Overview of companies where our graduates find their first job, represented in a word cloud.*