

Assessment report
Limited Programme Assessment

Master Embedded Systems

University of Twente

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1. Executive summary

In this executive summary, the panel presents the main considerations which led to the assessment of the quality of the Master Embedded Systems programme of University of Twente, which has been assessed according to the NVAO Assessment Framework.

The panel noted programme management followed up on the recommendations, made by the previous external assessment panel, such as strengthening the embedded systems orientation of the programme. In addition, programme management introduced a number of improvements, such as extending the common core in the curriculum and tailoring the homologation courses to the students' needs.

The programme's name, Master Embedded Systems, matches its contents and corresponds to the names of similar programmes.

The panel considers the Master Embedded Systems programme of University of Twente to be an internationally distinctive and attractive programme and welcomes the objective to offer a dedicated embedded systems programme. The panel feels, however, the potential of the programme could be more fully exploited by further strengthening the collaboration of the programmes of the three Universities of Technology in the Netherlands in order to, among others, offer students the range of subjects available at these different Universities.

The panel is positive about the Domain-specific Frame of Reference Embedded Systems which has been drafted by management of the three programmes. The domain has been adequately described and the programme has been appropriately compared to authoritative international sets of requirements.

The panel approves of the intended learning outcomes of the programme, as these cover domain-specific knowledge and skills, research competencies and academic skills to be achieved by students adequately. The intended learning outcomes meet the requirements of the Domain-specific Frame of Reference and match the requirements of an academic master programme. The panel considers the intended learning outcomes of the programme to prepare students for positions in research and industry alike.

The participation of industry in the programme is satisfactory, to be deduced, among others, from the position of the External Advisory Board within the programme.

The panel considers the admission requirements and procedures of the programme to be adequate. The panel also appreciates the pre-master programme. Being positive about the homologation courses to remedy deficiencies of students in computer science or electrical engineering, the panel, nevertheless, welcomes the reduction in credits for these courses, as this will enable students to gain more in-depth knowledge of and skills in this domain. The panel advises to adopt the on-line homologation tool and to offer homologation courses on-line in order to help accomplishing this reduction.

The panel considers the intended learning outcomes to be met in the curriculum. The correspondence of learning outcomes and curriculum components is, however, addressed at a rather high aggregation level. The panel recommends to draft these relations in a more detailed way, in order to be able to identify more clearly overlap of and gaps between courses from the intended learning outcomes perspective.

The panel considers the curriculum of the programme to be quite appropriate. The panel is very positive about the specialisation courses and about the internship requirements and the graduation projects design and appreciates the research knowledge and skills taught in the curriculum. The panel advises, however, to adapt the common core courses to offer students a more comprehensive view on the embedded systems domain and to design the core courses more research-oriented and more embedded systems-specific.

The educational principles and the study methods of the programme are adequate and assist students in their learning processes. The panel advises to continue the blended learning projects and experiments in collaboration with the other Universities.

The study guidance in the programme is considered by the panel to be very good. The student-to-staff ratio is appropriate. The panel recommends monitoring the student success rates, as these seem to be decreasing the last years.

The panel is very positive about the lecturers in the programme. They are experts in their fields, while the vast majority of them have PhD's and a substantial number of them possesses BKO-certificates. The panel advises programme management to actively pursue the University of Twente target of 100 % BKO-certified lecturers in 2020. The lecturers have a good command of the English language. The panel especially welcomes the enthusiasm of the lecturers and their very student-centered approach.

The panel concludes the facilities for the programme to be very good.

The examination and assessment rules and regulations of the programme are regarded by the panel to be appropriate. They comply with Faculty assessment policy statements and with the University of Twente assessment framework.

The panel is positive about the responsibilities of the Examination Board c.q. the sub-committee for this programme, as these include monitoring the examinations and assessment procedures, the quality of the examinations and the students' achieving the intended learning outcomes of the programme. The panel would like to see, however, the Examination Board taking a more active role in performing these tasks.

The examination and assessment procedures in the programme ensure the validity, reliability and transparency thereof satisfactorily. The assessments of the internships are regarded by the panel to be adequate as well. Though the quality of the assessment procedures for the master thesis projects are not doubted by the panel, the panel would like to make some suggestions for further improvements. These are to elaborate the thesis guidelines and the thesis assessment form to allow for more clear substantiation of the grades given, to better align the grading of the projects conducted in industry and those done in research environments at the University, to verify whether industry representatives may be members of the graduation committee and to introduce 0.5 grades, to allow more differentiation between the projects.

Although the examinations of the courses of the programme are assessed by the panel to be satisfactory, the panel advises to inspect the degree of complexity in some of the core courses examinations. Having studied a total of fifteen master theses of graduates of the programme, the panel concluded these to be up-to-standard, meeting the learning outcomes of the programme. None of the theses has been assessed by the panel to be unsatisfactory and quite a number of these proved to be good or very good. The panel confirms the relatively high grades given for the theses.

The information provided on the graduates' careers leads the panel to consider the graduates to be well-prepared for the positions in this field on the academic master level. The careers show the graduates to meet the demands of industry as well as those of the academic world. The views expressed by the representatives of industry echo these positive findings.

The panel assesses the Master Embedded Systems programme of University of Twente to be satisfactory and recommends NVAO to grant re-accreditation to this programme.

Rotterdam, 14 September 2017

Prof. dr. ir. D.R.M. Stroobandt
(panel chair)

drs. W. Vercouteren
(panel secretary)

2. Assessment process

Certiked VBI received a request by University of Twente to conduct a limited programme assessment for the re-accreditation of the Master Embedded Systems programme.

Certiked requested the approval by NVAO of the proposed panel of experts to conduct this assessment. NVAO have given their approval. The panel composition was as follows (for more detailed information please refer to Annex 4 Assessment panel composition):

- Prof. dr. ir. D.R.M. Stroobandt, full professor Embedded Systems and Hardware Design, Ghent University (panel chair);
- Prof. dr. P. Marwedel, full professor Methods for Computer-aided Design of Integrated Circuits, Dortmund University of Technology (panel member);
- Dr. A.D. Pimentel, associate professor in System and Network Engineering Lab, University of Amsterdam (panel member);
- S. de Vries, general manager of the private company Chess Wise BV (panel member);
- E.E.M. Leo BSc, student Master programme Educational Sciences, University of Amsterdam, (student member).

On behalf of Certiked, drs. W. Vercooteren was responsible for the process coordination and for drafting the panel's report. All panel members and the secretary signed a statement of independence and confidentiality.

The panel conducted this assessment on the basis of the standards of the NVAO Assessment Framework of 19 December 2014 (Staatscourant nr. 36791).

The following procedure was adopted. The panel members studied the documents presented beforehand by programme management, including a number of theses (please refer to Annex 2 and 3: Documents reviewed and Theses reviewed). With respect to the selection and study of the theses, the panel proceeded in line with the NVAO Guidelines for the assessment of final projects during external assessments of 18 February 2015.

Before the date of the site visit, the panel chair and the panel secretary met to discuss the assessment procedures. Before the site visit date, all panel members sent in their preliminary findings, based on the information file submitted by programme management, sent in a number of questions to be put to the programme representatives on the day of the site visit and presented their findings about the theses, they had studied. The panel secretary summarised this information.

On 25 June 2017, the panel had a meeting to discuss the preliminary findings concerning the quality of the programme. During this preliminary meeting, the findings of the panel members, including those about the theses were discussed, and a number of questions were added to the list drafted beforehand. On the basis of this input, the panel secretary drew up a final list of questions, which served as a starting point for the discussions with the programme representatives during the site visit.

On 26 June 2017, the panel conducted a site visit on the University of Twente campus. The site visit schedule was in accordance with the schedule drafted beforehand (please refer to Annex 1 Site visit schedule). Programme management communicated the open office hours to the students and staff of the programme. No persons took the opportunity to meet with the panel.

In a closed session at the end of the site visit, the panel considered every one of the findings, weighed the considerations and drew conclusions regarding the quality of the programme. At the end of the site visit, the panel chair presented a broad outline of the findings to programme management.

Due to serious personal circumstances problems, the student member of the panel could not attend the site visits nor could she be present during the preliminary meeting of the panel. Having been informed about the absence of the student member, programme management agreed to proceed with the site visit as planned. The panel chair and the panel members also were in agreement to proceed with the site visit. At the completion of the assessment process, the panel agreed this process to have been conducted in a sound way.

A draft version of this report was finalised by the secretary, having taken into account the findings and considerations of the panel. The draft report was sent to the panel members, who studied the draft report and made a number of changes. The student member participated in this process. She found the assessment report to be a clear account of the panel findings and agreed to the panel considerations and recommendations. Thereupon, the secretary edited the final report. This report was presented to programme management to be corrected for factual inaccuracies. After having been corrected for these inaccuracies, the report was sent to the University's Board to accompany their request for re-accreditation of this programme.

3. Overview of the programme

3.1 Basic information about the programme

Administrative information about the programme:

Name programme in CROHO: M Embedded Systems
 Orientation, level programme: Academic Master
 Grade: MSc
 Number of credits: 120 EC
 Specialisations: Dependable Systems and Formal Methods, Embedded Control Systems, Energy-efficient Systems, Small Embedded Systems
 Location: Enschede
 Mode of study: Full-time (language of instruction: English)
 Registration in CROHO: 60331

Administrative information about the institution:

Name of institution: University of Twente
 Status of institution: Government-funded University
 Institution's quality assurance: Approved

Quantitative data about the programme

Percentage of students who completed the programme in three years (n+1)

Cohort	2011	2012	2013
Percentage of students	92 %	71 %	57 %

Lecturers' qualifications

Qualification	MSc	PhD	BKO*
Percentage of lecturers	100 %	95 %	53 %

*The number excludes the proportion of lecturers being exempt, which is 42 %.

The student-to-staff ratio is 19.4.

Number of contact hours per week for each of the years of the programme

Year of the programme	Year 1	Year 2
Number of contact hours per week	11.1	1.4

3.2 Main facts about the institution

The Master Embedded Systems programme is a programme of the Faculty of Electrical Engineering, Mathematics and Computer Science of University of Twente.

According to the University of Twente website, the mission statement of University of Twente is to be the leading entrepreneurial University, to anticipate future developments and to respond rapidly and effectively to the changing world around us. The University's staff are meant to be experts in their field and to assist in setting the agenda for public debate. University of Twente intends to interact on an ongoing basis with industry, research institutes and government to be able to generate ground-breaking research and world-class innovations. The University wants to produce outstanding graduates who excel by combining expertise from a range of fields, as they design solutions that meet the demands of the future, in the Netherlands and abroad.

More than 9,000 students study at University of Twente, being subdivided in more than 5,000 Bachelor students and about 4,000 Master students.

University of Twente comprises five faculties, being the Faculties Science and Technology, Electrical Engineering, Mathematics and Computer Science, Engineering Technology, Behavioural, Management and Social Sciences and Geo-Information and Earth Observation. These faculties offer 20 Bachelor programmes and 34 Master programmes.

3.3 Intended learning outcomes

The intended learning outcomes of the programme are as follows.

- The graduates of the programme have an all-embracing view on embedded systems, their design and their application in systems of various sizes (e.g. from small robots to cyber-physical and networked systems) including their evolution over time, demonstrated by an integration approach in system design.
- The graduates of the programme are capable of analysing the functional behaviour of complex embedded systems in a structural way using appropriate abstractions.
- The graduates of the programme are able to describe and study the non-functional aspects of embedded systems, e.g. resource boundedness and dependability.
- The graduates of the programme have a thorough knowledge of state-of-the-art methods and techniques for embedded systems design such as requirements engineering, hardware-software integration, performance modelling and analysis, validation and testing.
- The graduates of the programme are able to design embedded systems that satisfy the functional and non-functional requirements, taking into account the performance of the system during its lifetime. The graduates are also aware of costs and environmental issues making optimal use of available resources.
- The graduates of the programme have the ability to include other disciplines or involve practitioners of these disciplines in their work, where necessary. As engineers they are therefore able to work in a multidisciplinary setting.
- The graduates of the programme are able to conduct research and design independently and have a scientific approach to complex problems and ideas.
- The graduates of the programme possess intellectual skills that enable them to reflect critically, reason and form opinions.

- The graduates of the programme have the ability to communicate the results of their learning, thinking and decision-making processes at an international level.
- The graduates of the programme are aware of the temporal and social context of science and technology (comprehension and analysis) and can integrate this context in their scientific work.

3.4 Outline of the curriculum

In the table below, the programme curriculum has been presented.

Curriculum components	Credits
Embedded Computer Architectures	5 EC
System Validation	5 EC
Quantitative Evaluation of Embedded Systems	5 EC
Homologation courses	5 - 20 EC
Real-time Systems	5 EC
Embedded System Laboratory	5 EC
Specialisation electives	15 - 30 EC
First Year	60 EC
Internship/Electives	20 EC
Graduation Project (preparation phase)	10 EC
Graduation Project (thesis project)	30 EC
Second Year	60 EC
Total credits of the programme	120 EC

4. Overview of assessments

Standard	Assessment
Standard 1. Intended learning outcomes	Satisfactory
Standard 2: Teaching-learning environment	Satisfactory
Standard 3: Assessment	Satisfactory
Standard 4: Achieved learning outcomes	Satisfactory
Programme	Satisfactory

5. Findings, considerations and assessments per standard

5.1 Standard 1: Intended learning outcomes

The intended learning outcomes of the programme have been concretised with regard to contents, level and orientation; they meet international requirements.

Findings

Embedded systems are hardware/software systems which are built into devices or systems. Embedded systems fulfil dedicated functions within larger mechanical or electrical systems and control the quality and functionality of these systems or devices.

The main objectives of the Master Embedded Systems programme are to educate students in the academic and professional competencies for the design of embedded systems. Students are trained in domain-specific knowledge and skills with respect to embedded systems, this knowledge and these skills being multidisciplinary and being derived from the electrical engineering and computer science disciplines.

The programme is the result of the collaboration of the Master Embedded Systems programmes of University of Twente, Eindhoven University of Technology and Delft University of Technology. These programmes together drafted the Domain-specific Frame of Reference Embedded Systems, compiled identical intended learning outcomes for all programmes and designed curricula, to a large extent similar. Management of the three programmes meet regularly to discuss the adjustment of the programmes. The three Universities decided, however, not to pursue a joint-degree programme, allowing each of the programmes leeway in design and delivery.

In the Domain-specific Frame of Reference Embedded Systems, management of the three programmes specified the embedded systems domain. The programmes are in line with noted international sets of requirements for embedded systems programmes, such as those of the Embedded Systems Special Interest Group (ARTIST) and the European Association for Research and Development in Embedded Intelligent Systems (ARTEMIS).

Programme management drafted the intended learning outcomes (please refer to the complete list in section 3.3 of this report). As has been mentioned, these are identical for all three programmes of the collaborating Universities. In the intended learning outcomes, domain-specific knowledge and skills, design and research competencies, critical reflection skills, communication and collaborating skills and ethical and societal awareness are addressed. Programme management has demonstrated the intended learning outcomes to meet the domain-specific frame of reference requirements. In addition, programme management has shown the intended learning outcomes to comply with the Meijers criteria, being the Dutch Universities of Technology standard for the master level of the learning outcomes.

For the three programmes, a joint External Advisory Board is in place, with members representing industry. The members of the Board with whom the panel met, indicated the Board to be effective in voicing the industry's views on the programme.

Considerations

The panel approves of the objectives of the Master Embedded Systems programme of University of Twente. The panel considers this programme to be an internationally distinctive and attractive programme and welcomes the objective to offer a dedicated embedded systems programme. The panel feels, however, the potential of the programme could be more fully exploited by further strengthening the collaboration of the programmes of the three Universities of Technology in order to, among others, offer students the range of subjects offered at the three different Universities. The panel noted the number of students taking courses at other Universities at this moment to be quite limited.

The panel is positive about the Domain-specific Frame of Reference Embedded Systems which has been drafted by management of the three programmes. In this frame of reference, the embedded systems domain has been adequately described and the programme objectives have been appropriately compared to authoritative international sets of requirements.

The panel approves of the intended learning outcomes of the programme. These cover the domain-specific knowledge and skills, research competencies and academic skills to be achieved by students adequately.

The panel observed the intended learning outcomes to meet the requirements of the Domain-specific Frame of Reference Embedded Systems. They also comply with the Meijers criteria of the Dutch Universities of Technology and, therefore, to meet the requirements of an academic master programme.

The panel considers the intended learning outcomes of the programme to prepare students for positions in research and industry alike. The participation of industry in the programme is satisfactory, to be deduced, among others, from the position of the External Advisory Board within the programme.

Assessment of this standard

These considerations have led the assessment panel to assess standard 1, *Intended learning outcomes*, to be satisfactory.

5.2 Standard 2: Teaching-learning environment

The curriculum, staff and programme-specific services and facilities enable the incoming students to achieve the intended learning outcomes.

Findings

As has been indicated, the Master Embedded Systems programme is a programme of the Faculty of Electrical Engineering, Mathematics and Computer Science of University of Twente. Management of the programmes of the three Universities meet regularly to discuss the alignment of the programmes. In November/December of the first year, students from all three programmes meet in the *Embedded Systems Student Event*. The University of Twente Master Embedded Systems programme is managed by the programme director. Students and lecturers are represented in the Programme Committee, which gives the programme director advice on quality issues. The joint External Advisory Board of the three Universities advises programme management on the alignment with the professional practice. The Examination Board oversees the examinations and assessments of the programme.

The number of students enrolling in the programme fluctuated somewhat over the years, going from an influx of 30 students in 2011 via an influx of 14 students in 2013 to an influx of 16 students in 2015. The number of incoming students has been limited over the years. The proportion of foreign students fluctuates around 25 %. The proportion of female students is very limited. Programme management intends to raise the influx of students from the Netherlands as well as from abroad.

Students with bachelor degrees in computer science or electrical engineering or with equivalent qualifications are admitted to the programme. In case of deficiencies in, notably, electrical engineering or computer science, they may need to take homologation courses to a maximum of 20 EC. Programme management intends to reduce the homologation courses to a maximum of 15 EC and, subsequently, to 10 EC, freeing up time for embedded systems-related courses. Students with bachelor degrees in other fields of study or with vocational bachelor degrees should take the pre-master programme of 30 EC. Foreign students with deficiencies, normally, are not admitted. Students entering the programme are, in the first year, automatically registered at the other two Universities as well, this allowing them to take courses there.

Programme management showed in diagram form the relations of the curriculum components to the intended learning outcomes. From this diagram, it may be deduced all intended learning outcomes are adequately represented in the curriculum. The curriculum consists of common core courses (25 EC), specialisation or research topics courses (at least 15 EC), internship (optional, 20 EC), graduation project (10 EC for preparation phase and 30 EC for thesis project). The five core courses are shared by the three Universities and have similar learning goals. The core courses address, among others, design and testing methods, hardware architectures and real-time systems design and analysis. One of the core courses, *Quantitative Evaluation of Embedded Systems*, is jointly designed and delivered by the three programmes. In the specialisation courses, students may select one of the research topics offered by the research groups, participating in the programme. The research topics are *Dependable Systems and Formal Methods*, *Embedded Control Systems*, *Energy-efficient Systems* and *Small Embedded Systems*. Internships are taken by a number of students. Programme management ensures the research contents of the internship assignments and provides adequate guidance during the internships and a company visit. The graduation projects include the preparation phase, which encompasses a literature study and the master thesis project itself. A proportion of the graduation projects are done in companies. Programme management advises against theses in the internship company.

The master theses are intensively supervised. In these research-oriented thesis projects, students are required to demonstrate having achieved all of the intended learning outcomes.

The educational principles of the programme focus on interactive teaching, allowing students coming from heterogeneous backgrounds to reach the required level of knowledge and skills in this domain and activating students to take the learning processes into their own hands. The study methods adopted in the programme include lectures, tutorials, homework assignments, discussions on journal articles, lab sessions and practical assignments. Tele-lectures are adopted in a number of courses, allowing students from other universities to take these courses. The lack of personal interaction reduces the effectiveness of this study method. The number of contact hours is 11.1 hours per week in the first year and 1.4 hours per week in the second year. These numbers underestimate the real figures, as, among others, contact hours in internships and daily supervision by PhD students in graduation projects are not included.

Students are guided through the curriculum primarily by the programme mentor, who advises them on the homologation courses to take and the electives they can select. Students expressed being content about this guidance. Other, not study content-related issues may be discussed with the study advisor of the programme. The student-to-staff ratio in the programme is 19.4. The success rates of students having completed the programme within three years decreased from 92 % for the cohort of 2011 to 71 % for the 2012-cohort to 57 % for the cohort of 2013.

About 95 % of the lecturers in the programme are PhD's. The vast majority of the lecturers are active researchers in their fields of expertise. About 53 % of the lecturers obtained the Dutch University Teaching Qualification (BKO), testifying to their teaching capabilities. Many other lecturers (42 %) are exempt of this obligation, on account of their track records in teaching. The policy of the University of Twente is for all lecturers to have obtained the BKO-certificate by 2020. About 84 % of the lecturers have English language skills at C1 or C2 levels. In a number of courses, guest lecturers from industry address specific subjects. The students with whom the panel met, were very positive about the lecturers and found them very easily approachable.

Considerations

The panel considers the admission requirements and the admission procedures of the programme to be adequate. The panel is positive about the pre-master programme. The homologation courses to remedy deficiencies of students in either computer science or electrical engineering are appropriate for this purpose. The panel, however, welcomes the reduction in credits for these courses, as this will enable students to gain more in-depth knowledge of and skills in the embedded systems domain. The panel recommends to adopt the on-line homologation tool, being developed in Eindhoven, and to offer homologation courses on-line in order to help accomplishing this reduction.

Having studied the diagram presented by programme management, the panel considers the intended learning outcomes to be met in the curriculum. The correspondence of learning outcomes and curriculum components is, however, addressed at a level of rather high aggregation. The panel recommends to draft these relations in a more detailed way, in order to be able to identify more clearly overlap of and gaps between courses from the intended learning outcomes perspective.

The panel considers the curriculum of the programme to be quite appropriate. The panel is very positive about the specialisation courses as well as about the internship requirements. The panel advises, however, to adapt the common core courses to offer students a more comprehensive view on the embedded systems domain. In addition, the panel recommends to design the common core courses more research-oriented and more embedded systems-specific. The panel appreciates the research knowledge and skills taught in the curriculum.

The panel regards the educational principles and the study methods of the programme as adequate. They assist students in their learning processes. The panel advises to continue the blended learning projects and experiments in collaboration with the other Universities.

The study guidance in the programme is considered by the panel to be very good. The student-to-staff ratio is appropriate. The panel recommends monitoring the student success rates, as these seem to be decreasing the last years.

The panel is very positive about the lecturers in the programme. They are experts in their fields, while the vast majority of them have PhD's and a substantial number of them possesses BKO-certificates. The panel advises programme management to actively pursue the University of Twente target of 100 % BKO-certified lecturers in 2020. The lecturers have a good command of the English language. The panel especially welcomes the enthusiasm of the lecturers and their very student-centered approach.

The panel was offered the opportunity to visit some of the laboratories used in the programme. From this inspection and from the description of the facilities by programme management, the panel concludes the facilities to be very good.

Assessment of this standard

These considerations have led the assessment panel to assess standard 2, *Teaching-learning environment*, to be satisfactory.

5.3 Standard 3: Assessment

The programme has an adequate assessment system in place.

Findings

The examination and assessment rules and regulations of the programme comply with the Faculty of Electrical Engineering Mathematics and Computer Science assessment policy statements, which in turn correspond to the University of Twente assessment framework. For all of the programmes of the Faculty, an Examination Board is in place. For the Master Embedded Systems programme, a sub-committee of this Board is responsible for the examination rules and regulations, the quality of the examinations and ensuring the graduates have achieved the intended learning outcomes. The Examination Board appoints the examiners who will only be appointed if they have fulfilled their BKO-obligations. Handling cases of fraud or plagiarism is part of the Board's responsibilities.

The examination methods adopted in the courses depend on the nature of the learning goals to be assessed and include written examinations, assignments as well as papers as the results of theoretical and practical projects.

Examinations are drafted by examiners. These examinations include examination matrices, identifying the relations between the examinations and the course learning goals. In addition, the examinations include answering models in case of written tests and scoring models or rubrics in case of assignments. Examinations are peer-reviewed by another examiner. Students are given the right to inspect their examinations.

Internship plans have to be approved by the internship supervisor. Internships are graded by the supervisor, taking into account the written report, an individual interview and the company supervisor assessment.

As has been indicated, the graduation project consists of the preparatory phase and the master thesis. The preparatory phase is assessed on the basis of the report, submitted by the student. Students may only begin with their master thesis, if their thesis proposal has been approved by their supervisor. The master thesis project is assessed by the graduation committee, consisting of three examiners, one of which comes from another research group. In the case of industry-related thesis projects, a representative of industry may sit on this committee. The graduation committee assesses the master thesis project by means of the thesis assessment form, specifying the contents of the report, the process and the oral defence.

Considerations

The panel regards the examination and assessment rules and regulations of the programme to be appropriate, as these comply with Faculty assessment policy statements and with the University of Twente assessment framework.

The panel is positive about the responsibilities of the Examination Board c.q. the sub-committee for this programme, as these include monitoring the examinations and assessment procedures, the quality of the examinations and the students' achieving the intended learning outcomes of the programme. The panel would like to see, however, the Examination Board taking a more active role in performing these tasks. The Board may, among others, inspect samples of examinations or master theses.

The examination methods meet the curriculum components' learning goals and are satisfactorily diverse.

The panel considers the procedures with respect to the examinations and assessments appropriate, these procedures ensuring the validity, reliability and transparency thereof satisfactorily. The assessments of the internships are regarded by the panel to be adequate. Though the quality of the assessment procedures of the master thesis projects are not doubted by the panel, it is suggested to elaborate the thesis guidelines and the thesis assessment form, allowing for more clear substantiation of the grades given. In addition, the panel recommends to better align the grading of the master theses projects conducted in industry and those done in research environments in the University. Also, the panel advises to verify whether industry representatives may be members of the graduation committee. As the master thesis projects are graded in integers, the panel advises to introduce 0.5 grades, this allowing to differentiate between thesis projects.

Assessment of this standard

The considerations have led the assessment panel to assess standard 3, *Assessment*, to be satisfactory.

5.4 Standard 4: Achieved learning outcomes

The programme demonstrates that the intended learning outcomes are achieved.

Findings

Programme management recorded the grade points average of the graduates of the programme and the grades for the graduation projects for the last two years in order to illustrate the level achieved by the students. The grade point average of the graduates of the programme was 7.6 in recent years. The average grade for the graduation projects is 7.9. About 12 % of the theses led to scientific publications.

Graduates of the programme tend to have generous opportunities on the labour market and find suitable positions rather easily. Nearly all graduates are employed within three months after graduation. Graduates find jobs in the high-tech industry with start-up companies as well as with large, multinational enterprises. Graduates also may pursue academic careers. Some of the alumni with whom the panel met, expressed favouring to be more adequately prepared for careers in industry.

The representatives of industry with whom the panel met during the site visit, expressed to be content with the graduates' capabilities.

Considerations

Having studied the examinations of a number of courses of the programme, the panel assessed these examinations to be satisfactory. The panel advises, however, to inspect the degree of complexity in some of the core courses examinations.

The panel reviewed a total of fifteen master theses of graduates of the programme. Having studied these master theses, the panel concluded these to be up-to-standard, meeting the learning outcomes of the programme. None of the theses has been assessed by the panel to be unsatisfactory. Quite a number of theses proved to be good or very good. The panel confirms the relatively high grades given for the theses.

The information provided on the graduates' careers leads the panel to consider the graduates well-prepared for the positions in this field on the academic master level. The alumni careers show that the graduates meet the demands of industry as well as those of the academic world. The views expressed by the representatives of industry echo these positive findings.

Assessment of this standard

The considerations have led the assessment panel to assess standard 4, *Achieved learning outcomes*, to be satisfactory.

6. Recommendations

In this report, a number of recommendations have been listed. For the sake of clarity, these have been brought together below. The recommendations are the following.

- To exploit the potential of the programme more fully by further strengthening the collaboration of the programmes of the three Universities of Technology in order, among others, to offer students the range of subjects offered at the three different Universities.
- To adopt the on-line homologation tool and to offer homologation courses on-line in order to reduce the number of homologation courses credits in the programme.
- To draft the relations between the intended learning outcomes and the curriculum components in a more detailed way, to be able to identify more clearly possible overlap of and gaps between courses from the intended learning outcomes perspective.
- To adapt the common core courses in order to offer students a more comprehensive view on the embedded systems domain.
- To design the common core courses in more research-oriented and more embedded systems-specific ways.
- To continue experiments and projects on blended learning in collaboration with the other Universities.
- To monitor the student success rates of the programme, as these figures seem to be decreasing in recent years.
- To actively pursue the University of Twente target of 100 % BKO-certified lecturers in 2020.
- For the Examination Board, to take a more active role in ensuring their responsibilities and in performing their tasks.
- To elaborate the master thesis guidelines and the thesis assessment form, allowing for more clear substantiation of the grades given.
- To better align the grading of the master thesis projects conducted in industry and those done in research environments in the University.
- To verify whether industry representatives may be members of the graduation committee.
- To introduce 0.5 grades, this allowing to differentiate between thesis projects.
- To inspect the degree of complexity in some of the core courses examinations.

Annex 1 Site Visit Schedule

The site visit took place at the University of Twente Campus on 26 June 2017. The site visit schedule was as follows.

08.30 h. – 08.50 h.	Arrival and deliberations panel (closed session)
08.50 h. – 09.30 h.	Dean and programme management, including brief presentation Prof. dr. P. Apers (Dean of Faculty Electrical Engineering, Mathematics and Computer Science), dr. ir. A. Kokkeler (programme director)
09.30 h. – 11.00 h.	Programme management and core lecturers Dr. ir. A. Kokkeler (programme director), prof. dr. ir. G. Smit (core lecturer Embedded Computer Architecture I), prof. dr. ir. M. Bekooij (core lecturer Real-time Systems I), dr. ir. J. Broenink (core lecturer Embedded Systems Laboratory), prof. dr. M. Huisman (core lecturer System Validation), ir. B. Molenkamp (programme mentor, Programme Committee member)
11.15 h. – 12.00 h.	Examination Board Dr. ir. J. Broenink, ir. H. Scholten, dr. ir. P.T. de Boer
12.00 h. – 13.00 h.	Lunch panel (closed session), open office hours 12.00 h. – 12.30 h.
13.00 h. – 13.30 h.	Tour around facilities
13.30 h. – 14.30 h.	Lecturers and thesis' examiners Dr. ir. S. Gerez (lecturer Computer Architectures for Embedded Systems), prof. dr. ir. B. Haverkort (Design and Analysis for Communication Systems lecturer), dr. ir. L. Sprengers (lecturer Services, Cyber Security & Safety), prof. dr. P. Havinga (lecturer Pervasive Systems), dr. ir. J. Kuper (lecturer Computer Architecture for Embedded Systems lecturer), E. Wassink MSc (study advisor)
14.30 h. – 15.15 h.	Students and alumni R.K. Ramachandran (alumnus, PhD student), T. Bokhove (alumnus, Controllab), E. Bronkhorst (alumnus, Thales), R. Kers (student, Programme Committee member), A. Khattab (student), L. Visser (student), E. Rijnbeek (student)
15.15 h. – 15.45 h.	Representatives from industry Dr. ir. J. Jacobs (SOMmaps, Zuyd University of Applied Sciences, Fontys University of Applied Sciences, External Advisory Board member), ir. B. Pronk (Philips, External Advisory Board member), dr. ir. H. Schurer (Thales, External Advisory Board member), dr. ir. G. Rauwerda (Recore Systems)
15.45 h. – 17.15 h.	Deliberations panel (closed session)
17.15 h. – 17.45 h.	Main findings presented by panel chair to programme management

Annex 2 Documents reviewed

The panel studied the following documents, presented prior to the site visit:

- Critical Reflection 4TU Master Embedded Systems
- Subject-specific Frame of Reference Embedded Systems
- Overviews of curricula
- Outline description of curriculum components
- Teaching and examination regulations
- Overview of allocated staff
- Staff qualifications
- List of graduates of the last two years (anonymised)
- Success rates
- Average number of hours of face-to-face instruction

In addition, the panel members were offered additional information on various aspects of the programme.

On the day of the site visit, programme management presented the following documents:

- Literature
- Course material (representative selection)
- Tests and examinations and assignments (representative selection)
- Intended learning outcomes and curriculum components matrix (draft)
- External Advisory Board minutes
- Examination Board annual reports
- Programme Committee minutes

In addition, the panel members were given access to the programme's electronic learning environment

Annex 3 Theses reviewed

The theses of the following 15 students have been selected for review by the panel

- 1126377
- 1279890
- 1189360
- 0087815
- 1349678
- 1255088
- 0021806
- 1382802
- 1164406
- 1109480
- 1376330
- 1003992
- 1505920
- 0144053
- 0144002

Annex 4 Assessment panel composition

The assessment panel had the following composition:

- Prof. dr. ir. D.R.M. Stroobandt, full professor Embedded Systems and Hardware Design, Ghent University (panel chair);
- Prof. dr. P. Marwedel, full professor Methods for Computer-aided Design of Integrated Circuits, Dortmund University of Technology (panel member);
- Dr. A.D. Pimentel, associate professor in System and Network Engineering Lab, University of Amsterdam (panel member);
- S. de Vries, general manager of the private company Chess Wise BV (panel member);
- E.E.M. Leo BSc, student Master programme Educational Sciences, University of Amsterdam, (student member).

Prof. dr. ir. D.R.M. Stroobandt (panel chair)

Mr. Stroobandt is full professor Embedded Systems and Hardware Design at Ghent University. He graduated from Ghent University as a Master of Science in Electrical Engineering. Subsequently, he took his doctorate in Electrical Engineering from this University. He has been intensively engaged in scientific research as well as in academic education in his field of expertise. Mr. Stroobandt supervised a range of doctorate theses. He has won several scientific prizes and has published widely in peer-reviewed journals.

Prof. dr. P. Marwedel (panel member)

Mr. Marwedel is full professor Methods for Computer-aided Design of Integrated Circuits at Dortmund University of Technology. He took his doctorate from University of Kiel, Germany. Mr. Marwedel was, among others, member of the Academic Senate of Dortmund University of Technology and Dean of Studies at the Computer Science Department of this University. Mr Marwedel published a wide range of books as well as articles in peer-reviewed journals in his field of expertise.

Dr. A.D. Pimentel (panel member)

Mr. Pimentel is an associate professor in System and Network Engineering Lab at University of Amsterdam. He graduated as a Master of Science in Computer Science and took his doctorate in Computer Science from University of Amsterdam. He was engaged in scientific research in his field of expertise. He undertook numerous academic education activities as a teacher and in educational management. Mr. Pimentel published widely in peer-reviewed journals in this field of expertise.

S. de Vries (panel member)

Mr. De Vries is the general manager of the private company Chess Wise BV. He completed his studies in Electrical Engineering at Leeuwarden Polytechnic. He was subsequently employed by, among others, the companies Manudax and Microproject, working in the Netherlands and abroad. Mr. De Vries proceeded to found the company Chess Wise, a company specialised in wireless lighting management. Mr. De Vries is a non-executive director of Rabobank Haarlem.

E.E.M. Leo BSc (student member)

Ms. Leo is a student in the Master programme Educational Sciences of University of Amsterdam. Previously, she completed the Bachelor programme in Educational Sciences at this University. She was a member of the Educational Committee of her programme and vice-chair of the Student Council of the Faculty of Social and Behavioural Sciences of University of Amsterdam. Ms. Leo participates as a student member on a regular basis in NVAO-accreditation panels.