MSc Embedded Systems
Eindhoven University of Technology

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Project code P2203

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Summary

Standard 1. Intended learning outcomes

The MSc Embedded Systems has formulated appropriate goals and learning outcomes on an academic master's level. These are clearly aligned with the expectations of the academic and professional field through the Consolidated Requirements in the domain-specific framework of reference. Further alignment is achieved through the External Advisory Board, which the panel considers to be a very valuable platform for interaction with the professional field. The connection with industry in the Brainport area is a strong characteristic of the MSc. Regarding the collaboration between the three universities that offer Embedded Systems programmes, the panel recommends exploring opportunities to create further benefits for students and staff.

Standard 2. Teaching-learning environment

The panel found that the ILOs of the MSc Embedded Systems have been appropriately translated into a well-structured curriculum. The structuring of flexible components of the curriculum into streams, as well as personal advice by the academic mentor, help students compose a coherent curriculum. The challenge-based learning concept of the programme that the programme is currently introducing is a good fit for the programme, and offers students the opportunity to work on challenges derived from industry. The choice to offer an English-language programme fits the highly international context of the MSc as well as that of the academic and professional fields. The panel supports the initiative to define skills learning trajectories in the curriculum, and advises to include specific attention to ethical and societal components of technologies.

The panel concludes that the curriculum is feasible, with sufficient attention paid to the heterogeneous background of students. The panel applauds the considerable decrease in study duration due to the restructuring of the graduation phase. Students are well-supported and receive sufficient guidance. The panel advises to further strengthen the mentorship programme to reach out to students that do not feel free to seek guidance. Students report to miss a community feeling: the panel advises the programme to consider creating a physical space where students can meet. The teaching staff is appreciated by students and well-qualified to teach in the programme, bringing developments in both research and industry into the courses. There is sufficient attention for the challenges of high workload of staff members, for instance through co-development of courses by senior and junior staff members, and other teacher support.

Standard 3. Student assessment

The panel concludes that the MSc's assessment system is solid, with a clear relation between the course objectives, assessment methods and ILOs detailed in the assessment plan. The assessment methods are varied, and there is a fitting assessment policy that pays sufficient attention to individual performance in group projects and provides checks and balances to safeguard the quality of assessment. The Examination Committee is proactive and in control of assessment quality assurance with regular checks and sampling. The panel recommends setting up a more structural assessment of skills, coupled with the planned skills learning trajectory. Thesis assessment is well-designed, with solid assessment rules and procedures, and an insightful form and associated rubrics. To even further improve thesis assessment, the programme should pursue more uniformity in the quantity of feedback provided to students on the assessment form.

Standard 4. Achieved learning outcomes

The panel concludes that quality of the theses as well as the job prospectives show that students of the MSc Embedded Systems achieve the intended learning outcomes. The high exit level is further demonstrated by the high number of publications resulting from student work.

Score table

The panel assesses the programme as follows:

MSc Embedded Systems

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Student assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

Prof. dr. Andy Pimentel
Chair

Peter Hildering MSc
Secretary

Date: 5 September 2023

Introduction

Procedure

Assessment

On 10 May 2023, the masters programme Embedded Systems of Eindhoven University of Technology was assessed by an independent peer review panel as part of the cluster assessment Embedded Systems. The assessment cluster consisted of 3 programmes, offered by the institutions Delft University of Technology, Eindhoven University of Technology and University of Twente. The assessment followed the procedure and standards of the NVAO Assessment Framework for the Higher Education Accreditation System of the Netherlands (September 2018).

Quality assurance agency Academion coordinated the assessment upon request of the cluster Embedded Systems. Peter Hildering MSc acted as coordinator and secretary in the cluster assessment. He has been certified and registered by the NVAO.

Preparation

Academion composed the peer review panel in cooperation with the institutions and taking into account the expertise and independence of the members. On 7 February 2023, the NVAO approved the composition of the panel. The coordinator instructed the panel chair on his role in the site visit according to the Panel chair profile (NVAO 2016) on 16 January 2023.

The programme composed a site visit schedule in consultation with the coordinator (see appendix 3). The programme selected representative partners for the various interviews. It also determined that the development dialogue would be made part of the site visit. A separate development report was made based on this dialogue.

The programme provided the coordinator with a list of graduates over the period 2020-2022. In consultation with the coordinator, the panel chair selected 15 theses per programme. He took the diversity of final grades and examiners into account, as well as the various tracks. Prior to the site visit, the programme provided the panel with the theses and the accompanying assessment forms. They also provided the panel with the self evaluation report(s) and additional materials (see appendix 4).

The panel members studied the information and sent their findings to the secretary. The secretary collected the panel's questions and remarks in a document and shared this with the panel members. In a preliminary meeting, the panel discussed the initial findings on the self-evaluation report and the theses, as well as the division of tasks during the site visit. The panel was also informed on the assessment framework, the working method and the planning of the site visits and reports.

Site visit

During the site visit, the panel interviewed various programme representatives (see appendix 3). The panel also offered students and staff members an opportunity for confidential discussion during a consultation hour. No consultation was requested. The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel publicly presented the preliminary findings.

Report

The secretary wrote a draft report based on the panel's findings and submitted it to a colleague at Academion for peer assessment. Subsequently, the secretary sent the report to the panel for feedback. After processing this feedback, the secretary sent the draft report to the programme in order to have it checked for factual irregularities. The secretary discussed the ensuing comments with the panel chair and changes were implemented accordingly. The panel then finalised the report, and the coordinator sent it to the programme.

Panel

The panel assessing the masters programme Embedded Systems at Eindhoven University of Technology consisted of the following members:

- Prof. dr. Andy Pimentel, professor of Embedded Computer Systems, University of Amsterdam (chair);
- Prof. dr. sc. Jari Nurmi, professor of Computer Engineering, Tampere University;
- Prof. dr. Wim Van Petegem, professor of Engineering Technology and Educational Policy, KU Leuven;
- Canan Kasaci-Öztürk MSc, team leader and product owner at ASML;
- Nienke Wessel BSc, master's student in Computing Science: Data Science and in Linguistics, Radboud Universiteit (student member).

Information on the programme

Name of the institution:	Eindhoven University of Technology
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive

Programme name:	Embedded Systems
CROHO number:	60331
Level:	Master
Orientation:	Academic
Number of credits:	120 EC
Specialisations or tracks:	Systems on Chip (SoC) Embedded Software (ESW) Embedded Networking (ENW) Cyber-Physical Systems (CPS)
Location:	Eindhoven
Mode(s) of study:	Fulltime
Language of instruction:	English
Submission date NVAO:	1 November 2023

Description of the assessment

Standard 1. Intended learning outcomes

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

Findings

The MSc Embedded Systems at Eindhoven University of Technology (TU/e) is offered by the Department of Mathematics and Computer Science (M&CS) in collaboration with the Department of Electrical Engineering (EE). It is organized in the context of the Computer Science domain of the TU/e Graduate School, and has an annual intake of 50-60 students. The MSc Embedded Systems aims to enable graduates to design innovative embedded systems: hardware/software systems that provide application-specific control and operation of devices. Typical examples of embedded systems are those found in home automation, autonomous vehicles and smart energy grids. These systems should be reliable and resource-efficient, making efficient use of energy, as well as computational and network resources. Graduates should be able to play a leading role in the development of embedded systems in scientific research, industry or governmental organizations.

The MSc Embedded Systems started out in 2006 as a collaborative master between the three TUs (Technical Universities) in the Netherlands. Although the programmes started to develop towards more independence in recent years, there is still close collaboration. The programmes have jointly composed Consolidated Requirements: requirements related to knowledge and skills that form the basis of all three curricula. These have been derived from the domain-specific framework of reference (DSFR) that was constructed by the three MScs in a joint effort. In constructing this DSFR, the programmes analyzed a number of relevant international frameworks related to cyber-physical systems. They also conducted an international benchmark of comparable MSc programmes. The resulting core competencies were connected to the MSc requirements as described in the Meijer's criteria, the interpretation of the Dublin descriptors often used by engineering programmes. Each of the three programmes translated the DSFR's Consolidated Requirements into a set of Intended Learning Outcomes (ILOs).

The panel studied the profile and aims, the DSFR and the intended learning outcomes of the programme. It concludes that the MSc has composed an appropriate set of ILOs that clearly reflect the academic master's level and the requirements of the field through the Meijer's criteria and the DSFR. The DSFR describes a comprehensive overview of the field of Embedded Systems, using relevant international frameworks and benchmarks. Within this common core, the individual programmes are free to highlight certain aspects. According to the panel, the TU/e MSc can be characterized by its strong connections to the Brainport area, leading to close collaborations with companies in projects and assignments in challenge-based courses. The panel considers this to be a strong feature of the programme, that was also recognized by the students and alumni the panel interviewed.

External Advisory Board

The MSc has an External Advisory Board of professional field representatives that is shared between this programme and the other two Embedded Systems-programmes at UT and TUD. This board meets at least once per year to provide solicited and unsolicited advice relevant to the development of the programme. It is regularly consulted regarding curriculum developments, and provides input for the DSFR. The panel appreciates that the three TU programmes have strong connections to the professional field through the

External Advisory Board. The panel had the opportunity to speak to the External Advisory Board during the site visit, and found that its members are very much involved in the programmes and actively contribute to discussions on programme development. The panel considers this board an asset of the programmes and encourages them to keep investing in it.

4TU.Federation collaboration

As discussed above, the MSc Embedded Systems was originally designed as a collaborative 4TU.Federation master involving three of its universities. At the time of the previous accreditation in 2017, the three Dutch Embedded Systems MSc programmes shared a common set-up, with five compulsory core courses offered by all three TU universities covering the Consolidated Requirements of the DSRF, and opportunities for students to specialize in courses at all three universities. The previous panel recommended exploring further opportunities for strengthening the collaborative nature of the programmes. However, due to local developments in the programmes, which included curriculum renewals and the merger between the MSc Embedded Systems and the MSc Computer Engineering in Delft, this intention took another turn. From 2021 onwards, the three programmes decided to create more room for differentiation, leaving the decision on how to compose their curriculum and develop their profile to the individual programmes. Students are still given the opportunity to follow courses at the other three universities, and there is frequent informal interaction between the programme managements to share experiences.

During the site visits at all three universities, the panel discussed the current status of the collaboration with programme management, teaching staff and students. The panel understands and approves of the reasons behind the recent divergence of the programmes. Further integration as suggested by the previous panel is no longer self-evident. Due to the flexibility of the curricula and the many opportunities for a tailor-made curriculum offered within the own university, student interest in taking courses at other universities has decreased, especially due to the travel involved. The panel noted that the collaboration is still very fruitful on a management level, and that there are individual initiatives between teachers that align on the organization of similar courses. As such, it is positive on the current situation.

In case the programmes want to pursue new initiatives for student exchange between the programmes, the panel noted down some ideas mentioned in discussions at the three site visits. Since several courses taught in the various programmes are still quite similar, multi-university teacher teams could co-develop courses and share content. Students could also work on team challenges, either in mixed teams or in student competitions between the universities. This might also strengthen the community feeling and the sense of identity as an Embedded Systems student (see standard 2). Furthermore, using the experiences from the COVID-19 pandemic, it might be feasible to offer (parts of) shared courses online. The panel recommends exploring the abovementioned opportunities and, if there is sufficient enthusiasm between all three partners, work on implementing this to the benefit of students and staff.

Considerations

The MSc Embedded Systems has formulated appropriate goals and learning outcomes on an academic master's level. These are clearly aligned with the expectations of the academic and professional field through the Consolidated Requirements in the domain-specific framework of reference. Further alignment is achieved through the External Advisory Board, which the panel considers to be a very valuable platform for interaction with the professional field. The connection with industry in the Brainport area is a strong characteristic of the MSc. Regarding the collaboration between the three universities that offer Embedded Systems programmes, the panel recommends exploring opportunities to create further benefits for students and staff.

Conclusion

The panel concludes that the programme meets standard 1.

Standard 2. Teaching-learning environment

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

Findings

Curriculum

The curriculum of the MSc Embedded Systems consists of a compulsory common core (25 EC), stream courses (specialization, 15 EC), electives (40 EC) and a graduation phase (40 EC).

- The *compulsory core* consists of five courses that cover the fundamentals of the design of embedded systems, such as requirement engineering, modelling, architectures, testing and verification.
- In the *stream courses*, students can choose between four specializations that provide in-depth knowledge and skills in certain aspects or applications of embedded systems. The streams are Systems on Chip (hardware), Embedded Software (software), Embedded Networking and Cyber-Physical Systems. Students follow three core courses in their stream of choice, and choose a minimum of 15 EC of stream-specific elective courses.
- The remaining 25 EC of the *electives* can be spent on additional specialization courses, homologation courses or on an internship. The goal of the optional 15 EC internship is to gain experience in the future professional field. Students typically execute a project in academia or in industry. To avoid a situation where students spend too much time away from a university, students are not allowed to do both an internship and the graduation project in industry. Students are formally supervised by an academic staff member, with daily supervision provided by an external supervisor. An often used elective is the Academic Writing in English course, that the programme recommends to students that need additional practice with their writing skills.
- In the *graduation phase*, students prepare (10 EC) and execute (30 EC) an individual research project under supervision of a staff member from one of the research groups involved. This project is usually part of one of the research projects of the group or part of an industry assignment. In the preparatory course, students conduct a literature review on their topic of choice and compose the research question for the graduation project.

The panel studied the curriculum of the MSc and concludes that it is a well-structured curriculum with a good balance between core and flexible content. It learnt that the curriculum was adapted and restructured in answer to the recommendations of the previous accreditation panel, which recommended a realignment of the courses with the ILOs and the DSFR. The panel notes with appreciation that the core courses cover the main intended learning outcomes regarding knowledge as described in the DSFR, providing students with an essential basis for the remainder of the curriculum. The streams help students make coherent curriculum choices, and again offer a core with elective components.

Skills are embedded more implicitly in the courses, with challenge-based assignments offering students the opportunity to work on skills such as communication and teamwork, and with research skills embedded in the preparation and execution of the thesis project. The panel learnt from the interviews during the site visit that the Graduate School is working on defining skills learning trajectories in the various MSc programmes, which the panel encourages. It thinks that integrating skills education more visibly in the courses will ensure

that all students encounter this in a comparable way throughout their studies. As part of this development, the panel recommends including explicit attention to possible ethical and societal consequences of the technologies students work on, as this is an increasingly important skill for future engineers. This could for instance include an ethical reflection in reports and projects where technologies with societal consequences are discussed.

Didactic concept
The programme is currently moving towards challenge-based learning as teaching method within the programme. This method is focused on learning in a context with considerable teacher-student interaction, where challenges and assignments in courses are often derived from real-world cases. These cases are often directly taken from an industrial context from one of the companies in the Brainport area. Students generally work on these challenges in teams, with the aim of designing (part of) an embedded system for a particular purpose. Due to the relatively low student numbers, there is ample opportunity for interactions in the lectures and practice tutorials. Particularly in the graduation project, students learn by doing through a master-apprentice approach, where they typically study a sub-project within a larger research project of their supervisor.

The panel appreciates the challenge-based learning concept, and thinks that this is a good fit for the programme. The panel learnt from students that they support taking this approach further. They mentioned that some courses can still be theory-focused, and would prefer more practical work in these courses. The panel recommends monitoring the use of the challenge-based approach throughout the curriculum, and determining where opportunities for further implementation can be found.

The panel learnt from the interviews that students appreciate the option to have an internship, but that companies often find the duration of 15 EC too short. The panel understands that longer internships are probably not feasible in the current curriculum, but suggests that there might be other options beside an individual internship to familiarize students with the professional field. The challenge-based learning approach of the MSc allows for concepts such as having teams of students work on a particular company project, or a larger challenge-based project that student teams tackle on campus. The panel in no way aims to impose this idea on the programme, but invites the programme to freely explore this.

Language and internationalization
The curriculum (as well as the name) of the MSc Embedded Systems is in English, as a large part of graduates of the programme will be active in an international industrial or academic context. Students who have never studied outside the Netherlands are encouraged by the Graduate School to gain international experience, for instance by taking electives, following an internship or completing (part of) the graduation project abroad. Until 2022-2023, it was possible for students to register for the dual degree EIT Digital Embedded Systems, where they would follow part of their curriculum at one of the European partner universities to receive two master's diplomas. Due to the low popularity of this option and the associated administrative overhead, TU/e decided to discontinue participation in this dual degree per 2023-2024.

The panel concludes that the choice for English as language of instruction (as well as an English-language programme name) fits the predominantly international character of the academic and professional field. It is embedded in a strongly international context, including students, teaching staff and professional field, especially in the Brainport area where many of the graduates can be expected to work. The panel understands the reasons of the programme to discontinue the EIT Digital dual degree. Many students already have an international background, and for the rest there are sufficient other options for internationalization.

Guidance and feasibility

The programme directly admits students with a BSc CS or EE from one of the three TUs. To repair possible pre-knowledge deficiencies, students may include 2.5 EC of homologation units in their study programs: CS courses for EE graduates, and vice versa. Students from other backgrounds usually have additional deficiencies, which are determined by the programme before the start. Students can follow a maximum of 15 EC homologation courses or in the case of larger deficiencies, follow the 30 EC pre-master programme. In some cases, these pre-master courses can already be taken as electives during the bachelor's degree, minimizing study duration before entering the MSc. The panel appreciates the attention paid to student guidance at the start of the programme. There are several options to address possible deficiencies in pre-knowledge in the homologation courses and the pre-master. Course materials from homologation courses are available for all students, so (prospective) students that don't take the full course can still brush up their knowledge on specific topics in self-study. Some students indicated to the panel that they only learnt of this option after the start of the curriculum and would have liked this opportunity to prepare themselves. The panel recommends to include this more prominently in the communication to new students.

All students that are new to Eindhoven follow an introduction event before the start of the academic year, with both informative and social aspects. They get assigned a student mentor to introduce them to TU/e and Eindhoven. An academic mentor, an academic staff member from within the programme, helps advising the students on choosing a stream and electives, and submitting this individual curriculum to the Examination Committee for approval. In 2022, the programme introduced a more elaborate Study and Career Orientation programme, with several presentations from research groups, companies and fellow students to introduce students to current topics in industry and academia, as well as professional identity training, career workshops and mentor group meetings. These events are intended to help students develop research and professional interests, helping them to make curriculum choices and orient themselves on a future career.

The panel is positive on the student support in the programme, and thinks the mentorship provisions are good mechanisms to help students find their way into the programme, with the Study and Career Orientation programme helping students further develop themselves with an eye on their future careers. Students reported to the panel that, notwithstanding the efforts of the programme, some international students still feel overwhelmed at the start of the curriculum. Balancing finding your way in a new country and university, making curriculum choices and starting challenging courses can be tough for some. The panel learnt from discussions during the site visit that not all students initially feel free to make use of the mentorship options available to them. Students with less proactive mentors therefore sometimes miss out on opportunities for support. The panel recommends investigating how mentorship can be strengthened by putting student and academic mentors in a more proactive role at the start of the curriculum.

Even though students appreciate the short lines with teaching staff members and the group work in the courses, they reported to miss an overall community feeling within the programme. Students are spread out over multiple elective and individual course components. Furthermore, they are not connected to a single study association, but may join the computer science and/or electrical engineering study association. To promote a shared identity and community as embedded systems students, the students expressed the wish for a physical location on campus where they can meet and work together. The panel supports this, and asks the programme whether this can be realized.

In general, the panel concludes that the curriculum is feasible. This is reflected in favourable success rates, with 80% of students graduating with a study delay of one year or less. Especially in comparison to similar programmes and the programme's own success rates in the past (with 50% or more taking over three years to complete the curriculum), this can be considered a success. The programme management mainly

attributes this improvement to the restructuring of the thesis trajectory, with a mandatory preparatory course for all students where they prepare their research proposal, and a fixed duration with a deadline. A student who takes longer than one year must stop and start a new graduation assignment. This helped reduce the prolonged duration of thesis projects, which was the main source of study delay. The panel appreciates this and considers this to be a good practice.

Teaching staff

The teaching staff of the programme is associated with the Departments M&CS and EE, and for the large majority consists of active researchers in fields related to Embedded Systems. All have a PhD, and there are over 20 full professors associated with the programme. Research-based education is an explicit aim of the programme, which is pursued to keep the curriculum up-to-date and to connect to the research focus of the teaching staff. Furthermore, the teaching staff members have many connections to the professional field. These often function as guest lecturers in courses. Such collaborations further contribute to keeping the curriculum in line with developments and trends in the field. 85% of the teaching staff is in possession of the University Teaching Qualification (UTQ) or in the process of obtaining this. The remaining staff members have an exemption based on previous experience or due to a small part-time contract. Furthermore, all lecturers are required to be proficient in English.

The panel is positive on the quality and quantity of the teaching staff. Sufficient attention is paid to professionalization through the UTQ, and to proficiency to teach in an English-language programme. The teaching staff has very relevant research expertise in the field covered by the programme. They bring this into the curriculum in the courses and the thesis projects. The guest lecturers from industry add to the professional relevance of the courses. The panel noted from the interviews that the teaching staff members are enthusiastic and appreciated by students.

As is often the case, teaching staff members sometimes experience a generally high workload. This is most prominently the case with the more junior staff members, who need more time to set up courses. To alleviate this workload, the panel learnt that several senior staff members engage in co-development of courses with junior staff members. The panel very much appreciates this initiative, and considers that this good practice could be further implemented throughout the curriculum. Furthermore, the faculty provides staff members with support through the Teacher Support part of the Course Support Team, that can help organize and develop courses. The panel understood that the long-term aim of the MSc is to grow in student numbers. This makes it all the more urgent that the resources for organizing this remain sufficient.

The panel and programme management discussed the unfavourable gender balance in the staff and student population. The panel understands that stereotyping of engineering and computer science already starts at a young age, and goes beyond the sphere of influence of the programme. It encourages staff members to engage in promoting engineering in high schools and invite students to visit the university. Regarding staff diversity, the panel sees that the faculty and university in general pursue various initiatives to promote gender balance, which the panel supports and encourages.

Considerations

The panel found that the ILOs of the MSc Embedded Systems have been appropriately translated into a well-structured curriculum. The structuring of flexible components of the curriculum into streams, as well as personal advice by the academic mentor, help students compose a coherent curriculum. The challenge-based learning concept that the programme is currently introducing is a good fit for the programme, and offers students the opportunity to work on challenges derived from industry. The choice to offer an English-language programme fits the highly international context of the MSc as well as that of the academic and

professional fields. The panel supports the initiative to define skills learning trajectories in the curriculum, and advises to include specific attention to ethical and societal components of technologies.

The panel concludes that the curriculum is feasible, with sufficient attention paid to the heterogeneous background of students. The panel applauds the considerable decrease in study duration due to the restructuring of the graduation phase. Students are well-supported and receive sufficient guidance. The panel advises to further strengthen the mentorship programme to reach out to students that do not feel free to seek guidance. Students report to miss a community feeling: the panel advises the programme to consider creating a physical space where students can meet. The teaching staff is appreciated by students and well-qualified to teach in the programme, bringing developments in both research and industry into the courses. There is sufficient attention for the challenges of high workload of staff members, for instance through co-development of courses by senior and junior staff members, and other teacher support.

Conclusion

The panel concludes that that the programme meets standard 2.

Standard 3. Student assessment

The programme has an adequate system of student assessment in place.

Findings

System of assessment

Assessment in the MSc Embedded Systems is based on the principle that the assessment method fits the learning objectives of the course, contributes to student learning and to the achievement of the programme's ILOs. A detailed programme-wide assessment plan is composed annually, describing the mapping of course assessment in relation to the ILOs, and the motivation behind the choice of assessment methods. Assessment methods include written exams, project reports, presentations and skills assessment. The internship is examined by the university supervisor based on an internship report and the performance of the student during the internship, with advice from the company supervisor.

The assessment policy is developed on a department level, and describes several quality assurance mechanisms to ensure the reliability, validity and transparency of assessment. Examples are the co-development of test and assignments of courses, and the monitoring of individual contributions to group projects. For the latter, the programme uses peer assessment, close tutoring and individual elements in the grading, such as individual presentations and/or questioning.

The programme shares an Examination Committee with the MSc Computer Science & Engineering, with representatives from both programmes as well as an external member. The Examination Committee checks the assessment plans of the programme, and safeguards the assessment of courses through checks by a subcommittee ('Borgingscommissie') that reports to the Examination Committee. The Examination Committee takes random samples of MSc theses on a regular basis to check the exit level of students as well as thesis assessment.

The panel studied the system of assessment, including the annual assessment plan, and interviewed the Examination Committee. It concludes that the programme has a solid system of assessment with an appropriate variety of assessment methods. The assessment plan clearly relates assessment of individual

curriculum components to the programme's ILOs, and is a valuable tool to monitor the variety of assessment methods throughout the curriculum. The interviews with students and teaching staff members confirmed that sufficient attention is paid to the assessment of individual contributions in group projects. This discourages free-riding. Skills assessment is ensured through a variety of assessment methods, but could be more structured to allow students to explicitly build up their skills throughout the curriculum. The panel considers the planned introduction of a skills learning trajectory (see standard 2) to be a good starting point for this more structured approach.

The Examination Committee is in control, and proactively monitors the quality of assessment in the programme. The regular checks of course and thesis assessment add to the safeguarding of assessment quality. During the interview, the panel and the Examination Committee discussed the implication of generative AI for assessment in the courses. Several strategies and policies are currently being discussed on a faculty and university level. The panel adds to this that the Examination Committee could reach out to the Examination Committees of the other two Embedded Systems programmes to discuss what the domain-specific consequences of these policies could be.

Thesis assessment

The thesis project is assessed by a graduation assessment committee consisting of three members, one of whom is the graduation supervisor. At least one of the members is required to be from a different research group than that of the graduation supervisor. In the case of a graduation project in industry, the external supervisor can be part of the graduation assessment committee, as long as there are always two formally appointed examiners from TU/e in the committee. Before starting the execution of their thesis, students have already completed the thesis preparation course, where their research proposal and set-up are separately assessed. The committee grades the project after the final defense by the student, based on consensus (or a vote if no consensus is reached). In the assessment of the final project, they grade the quality of the results, the final report, the presentation, the defense and the performance during the project, and give a final grade. Rubrics that accompany the assessment form help the committee in grading. The final grade is not a weighted average, but an overall impression that is required to be qualitatively substantiated.

As part of the assessment the panel studied 15 final projects of the programme and the accompanying assessment forms. The panel concludes that the thesis assessment procedure is appropriate. The rules for composing the graduation assessment committees add to the reliability and validity of thesis assessment. The panel appreciates the introduction of rubrics, which answers the recommendations of the previous panel on a better substantiation of the grades. The forms and rubrics are used in an insightful way, with attention to qualitative substantiation of the grades. The amount of feedback given on the form differs between examiners: sometimes the panel would have appreciated more explanation of a specific aspect on the form. The panel recommends striving towards more uniformity in this.

Considerations

The panel concludes that the MSc's assessment system is solid, with a clear relation between the course objectives, assessment methods and ILOs detailed in the assessment plan. The assessment methods are varied, and there is a fitting assessment policy that pays sufficient attention to individual performance in group projects and provides checks and balances to safeguard the quality of assessment. The Examination Committee is proactive and in control of assessment quality assurance with regular checks and sampling. The panel recommends setting up a more structural assessment of skills, coupled with the planned skills learning trajectory. Thesis assessment is well-designed, with solid assessment rules and procedures, and an insightful form and associated rubrics. To even further improve thesis assessment, the programme should pursue more uniformity in the quantity of feedback provided to students on the assessment form.

Conclusion

The panel concludes that that the programme meets standard 3.

Standard 4. Achieved learning outcomes

The programme demonstrates that the intended learning outcomes are achieved.

Findings

To determine the exit level of students, the panel studied 15 recent master's theses of the programme, taking care that a variety of grades and topics was covered. It concludes that all students convincingly achieve the intended learning outcomes of the programme. The theses covered a wide variety of topics and methods, and frequently showed solid engineering work, with designs and often also implementations of embedded systems. The panel learnt that MSc students co-authored 42 publications related to thesis projects in the past six years, and that 5 of these papers received best paper awards. The panel considers this to be further proof of the high level of the programme's graduates.

Based on a recent TU/e-wide alumni survey, graduates of the MSc Embedded Systems quickly find a job, more than half of them (which also includes international students) in one of the high-tech companies or research institutions in the Brainport region. The External Advisory Board confirmed that graduates of the programme are in high demand and generally valued.

Considerations

The panel concludes that quality of the theses as well as the job prospectives show that students of the MSc Embedded Systems achieve the intended learning outcomes. The high exit level is further demonstrated by the high number of publications resulting from student work.

Conclusion

The panel concludes that the programme meets standard 4.

General conclusion

The panel's assessment of the MSc Embedded Systems is positive.

Development points

1. Introduce the planned skills learning trajectory throughout the curriculum in order to make skills education and assessment more visible in the curriculum. Specific attention should be paid to reflection on ethical and social consequences of technologies.

2. Invest in community forming between students, for instance by creating a physical space where Embedded Systems students can meet and work together on campus.

3. Further strengthen the mentorship programme to reach out to students that do not feel comfortable to seek guidance.

4. Pursue more uniformity in the substantiation of the grades on the thesis assessment form.

Appendix 1. Intended learning outcomes

The graduate

1. has 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.
2. is capable of analyzing the functional behavior of complex embedded systems in a structural way using appropriate abstractions.
3. is able to describe and study the non-functional aspects of embedded systems, e.g., resource boundedness and dependability.
4. has 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.
5. is 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 graduate is also aware of costs and environmental issues making optimal use of the available resources.
6. has the ability and attitude to include other disciplines or involve practitioners of these disciplines in their work, where necessary. As an engineer the graduate is therefore able to work in a multidisciplinary setting.
7. is able to conduct research and design independently and has a scientific approach to complex problems and ideas.
8. possesses intellectual skills that enable critical reflection, reasoning and forming opinions.
9. has the ability to communicate the results of their learning, thinking and decision-making processes at an international level.
10. is aware of the temporal and social context of science and technology (comprehension and analysis) and can integrate this context in the scientific work.

Appendix 2. Programme curriculum

Figure 5.1. ES curriculum components.

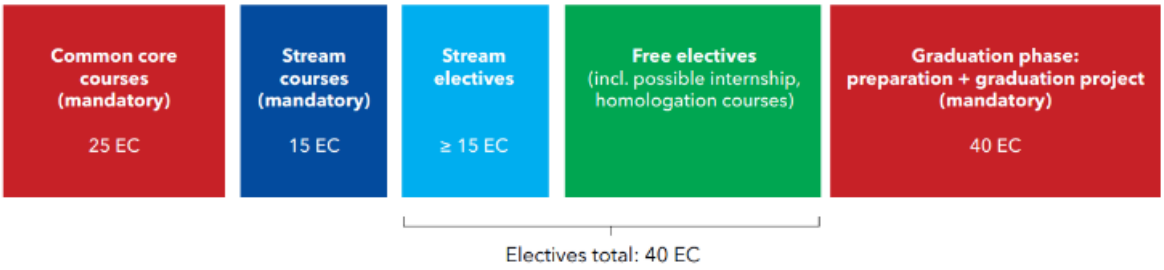


Figure 5.2. Systems on Chip (SoC) stream: A reference overview of the curriculum in diagram form with the relations to the ILO's.

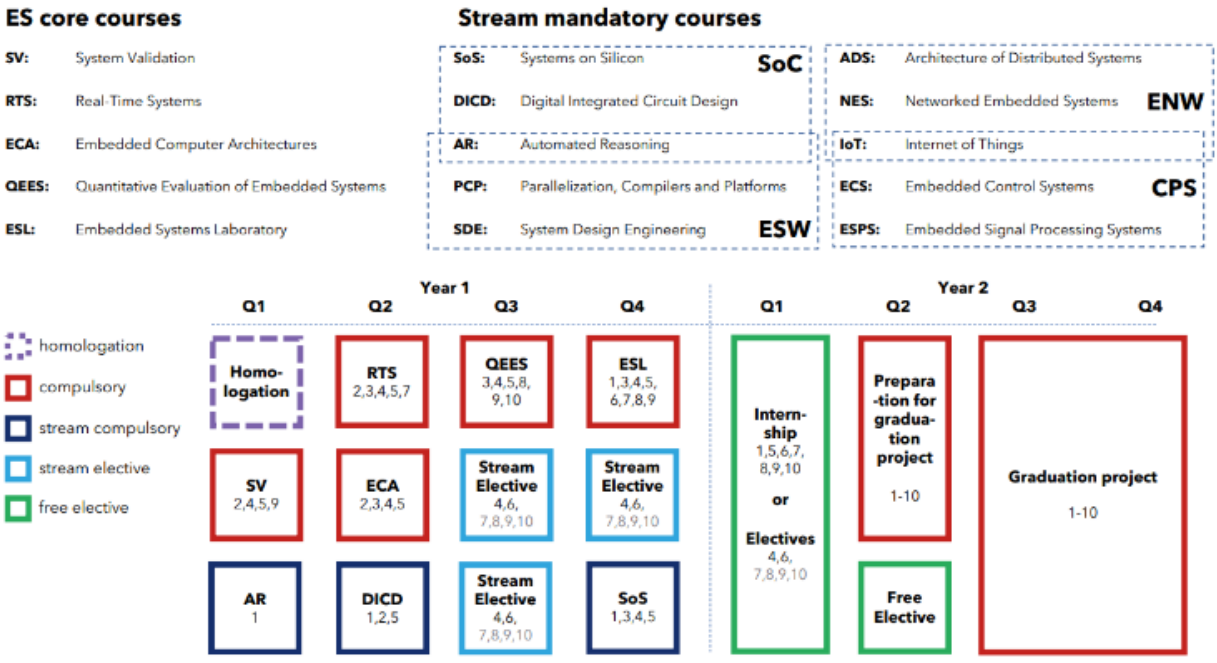


Figure 5.3. Embedded Software (ESW) stream: A reference overview of the curriculum in diagram form with the relations to the ILO's.

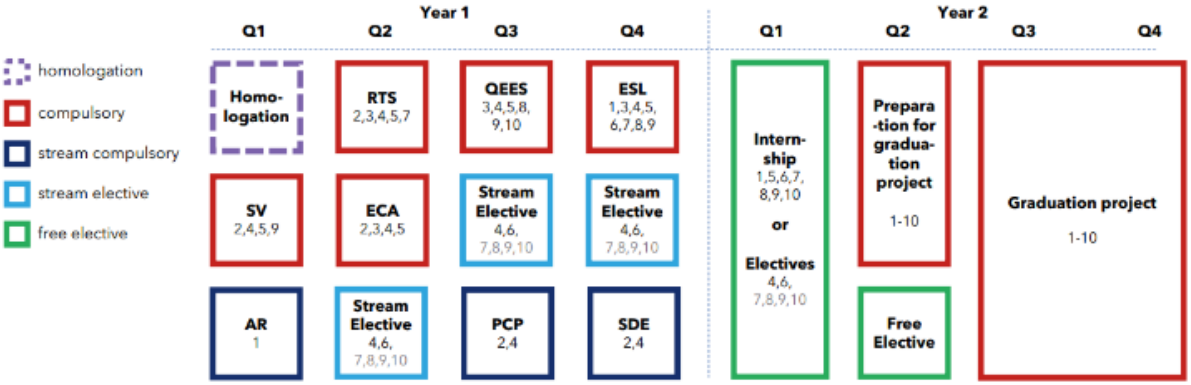


Figure 5.4. Embedded Networking (ENW) stream: A reference overview of the curriculum in diagram form with the relations to the ILO's.

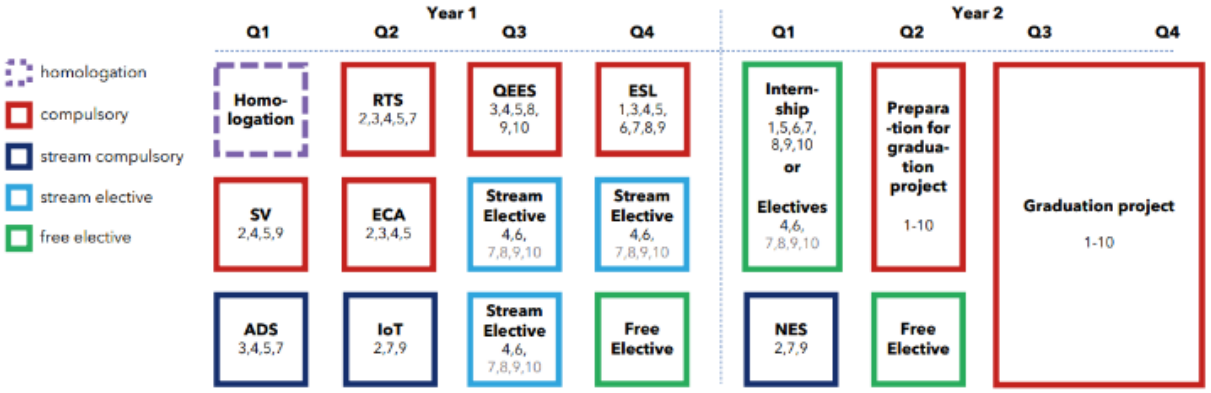
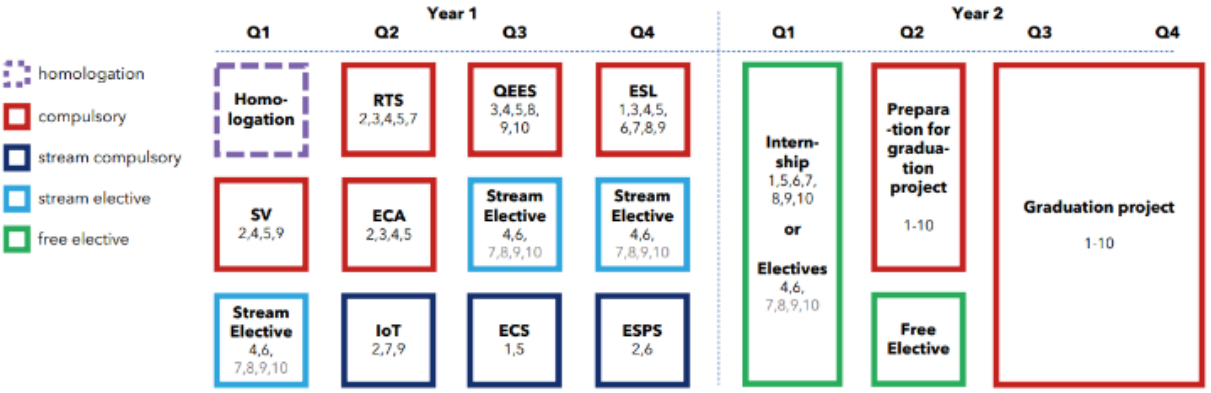


Figure 5.5. Cyber-Physical Systems (CPS) stream: A reference overview of the curriculum in diagram form with the relations to the ILO's.



Appendix 3. Programme of the site visit

Mon 8 May

16.00-19.00	Panel preparation (including consultation hour)

Tue 9 May

12.00-12:45	**General session: 3TU Collaboration** (during UT site visit)

Wed 10 May

08.30-09.00	Preparation
09.00-09.45	**Management TUe**
10.00-10.45	**Students and alumni TUe**
11.00-11.45	**Teaching staff TUe**
12.00-12:45	**General session: Industrial Advisory Board**
12.45-13.30	Lunch
13.30-14.00	**Examination Committee TUe**
14.00-14.30	Internal panel session
14.30-15.00	**Concluding session management TUe**
15.00-16.15	Internal panel session
16.15-16.45	**Feedback and conclusion**
16.45-17.15	**Development dialogue**

Appendix 4. Materials

Prior to the site visit, the panel studied 15 theses. Information on the theses is available from Academion upon request. The panel also studied other materials, which included:

- Report previous assessment committee
- Intended Learning Outcomes
- Intake and success rates of students
- Information External Advisory Board
- Domain-Specific Frame of Reference (DSFR)
- Overview of ES master courses, intended learning outcomes, assessments
- Competence matrix ES master's program (overall and per track)
- Program and Examination Regulations
- Graduation phase regulations
- Assessment policy
- TU/e English lecturer assessment
- Alumni survey results
- Peer-reviewed ES master student publications
- Reports of examination committee and programme committee
- Staff of the programme
- Examples of course materials