MSc Computer and Embedded-Systems Engineering
Delft University of Technology

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Project code P2203

Contents

Summary

Standard 1. Intended learning outcomes

The panel concludes that the MSc Computer and Embedded-Systems Engineering (CESE) has formulated a relevant profile as a MSc on the intersection between hardware and software. It draws from the strengths of the former MScs Embedded Systems (ES) and Computer Engineering (CE), and adds an integrative layer that fits the technological trends in electronic systems design. Its intended learning outcomes reflect the goals of both former programmes as well as the connection between these, and are formulated on an academic master's level. They 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. Regarding the collaboration between the three universities, the panel recommends exploring opportunities to create further benefits for students and staff.

Standard 2. Teaching-learning environment

The panel found that the curriculum of the MSc Embedded Systems is well-designed, covers all ILOs of the programme and includes the core elements of both the MSc ES and CE, as well as new integrative elements. There is a good balance between core, specialization and elective courses in the programme. There are sufficient elective elements to help students effectively compose their curriculum. The panel appreciates the didactic approach of the programme, which pays ample attention to interdisciplinary work, interactive teaching methods and close collaboration between students and staff members. Skills education, including attention to ethical and societal aspects of engineering, has been strengthened in the new curriculum. The panel supports the development of a skills learning pathway throughout the curriculum. The choice for English as language of instruction is appropriate, and fits the very international nature of the academic and professional field. The choice for Rust as programming language in the programme is appreciated by the panel, and shows that he programme is prepared to take a leading role in the field. In general, the panel recommends monitoring the implementation of the new curriculum choices in consultation with students and alumni, and make adaptations where necessary.

Student support and guidance are well-implemented in the programme. Students feel supported and part of a broader community. Some students feel that the courses are very challenging; the panel recommends investigating whether any changes are necessary to either the homologation courses or study load associated with courses to address this. The curriculum is feasible, although study duration is relatively long. The main reason is that students often take longer to make curriculum choices and complete their thesis projects. Both issues are currently being addressed by the programme through a more structured curriculum and by monitoring thesis progress. The panel supports this, and encourages the programme to continue these efforts. The teaching staff is appreciated by students and well-qualified to teach in the programme. Sufficient attention is paid to the challenges of high workload of staff members, for instance through co-development of courses. The staff is appreciated by students for their approachability, knowledge and dedication to strive for excellence in teaching.

Standard 3. Student assessment

The panel concludes that the assessment system of the programme is solid, with an appropriate variation of assessment methods and policies. The panel supports the planned constructive alignment of assessment in the new curriculum, and suggests connecting this to the creation of the skills learning pathway for skills assessment. The Board of Examiners is proactive and in control of assessment quality assurance with regular checks and sampling. Thesis assessment is appropriate, with solid assessment rules and procedures, and an

insightful form and associated rubrics. The panel is convinced that there are no structural issues regarding thesis assessment: the substandard thesis that stayed under the radar of the quality assurance procedures of the programme was an unfortunate incident under special circumstances that is unlikely to reoccur. The panel noted with appreciation that the Board is planning to step up its control mechanisms to prevent another such incident. The panel also advises to further enforce more extensive qualitative feedback on the assessment forms, especially in the case of particular circumstances.

Standard 4. Achieved learning outcomes

The quality of the theses as well as the job prospectives and satisfaction of the alumni convinced the panel that students of the MSc CESE achieve the intended learning outcomes.

Score table

The panel assesses the programme as follows:

MSc Computer and Embedded-Systems Engineering

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 May 11th 2023, the masters programme Computer and Embedded-Systems Engineering of Delft 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 of the MSc Embedded Systems (ES) and the MSc Computer Engineering (CE) over the period 2019-2022, as there are no graduates yet from the new integrated CESE curriculum after the merger (see report). In consultation with the coordinator, the panel chair selected 8 theses from ES, and 7 from CE. He took the diversity of final grades and examiners into account. 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 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 chair 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 Computer and Embedded-Systems Engineering at Delft 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:	Delft University of Technology
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive
Programme name:	Computer and Embedded-Systems Engineering
CROHO number:	60988
Level:	Master
Orientation:	Academic
Number of credits:	120 EC
Location:	Delft
Mode(s) of study:	Fulltime
Language of instruction:	English
Submission date NVAO:	1 November 2023

Description of the assessment

Scope of the assessment
The master's programme Computer and Embedded-Systems Engineering (CESE) at Delft University of Technology is the result of a merger between the MSc Embedded Systems (ES) and the MSc Computer Engineering (CE) per September 2023. In 2022, the two programmes were approved for merger by the NVAO via a so-called planning-neutral conversion process.

At the time of the site visit in May 2023, the programmes ES and CE were in the final stages of this merger. New shared intended learning outcomes (ILOs) and a shared curriculum for ES and CE had been launched for the academic year 2022-2023, and per 2023-2024, students formally register in the new MSc CESE. Students from the 2022-2023 cohort have the choice to switch to a MSc CESE registration, or to graduate with a diploma from their original MSc ES or CE. For the assessment, the panel took the realized results of the MSc programmes ES and CE into account, as well as the shared ILOs, 2022-2023 curriculum and the future outlook for the MSc CESE. In the remainder of this report, the MSc CESE is treated as the main unit for accreditation, with terms such as 'the programme' and 'the MSc' referring to the CESE programme. Where the original MSc programmes ES and CE are relevant, the names of these programmes will be specifically indicated.

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

Profile and aims
The master's programme CESE is organized by the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS) of TU Delft. It aims to educate students in designing and developing high-tech electronic systems that require multidisciplinary integration, specifically in the disciplines of electrical engineering and computer science. Students are taught a holistic view of electronic systems design, and learn to optimize system performance that meets design criteria.

As mentioned above, CESE originates from two separate MScs in Embedded Systems (ES) and Computer Engineering (CE). In 2022, the two programmes merged their intended learning outcomes (ILOs) and curricula, and are formally one MSc per September 2023. The choice to merge ES and CE originated from the convergence of the aims and curricula of both programmes over the course of the years. Whereas ES originally focused on software development for embedded electronic systems, and CE on designing hardware for complex computer systems, the traditional separation between hardware and software became increasingly blurred in modern systems. As a result EEMCS found itself with two closely related MSc programmes working on both hardware and software aspects of electronic systems. Through the merger, EEMCS aimed to create a single, multidisciplinary programme on the intersection of the hardware and software domains.

According to the panel, the programme has a very relevant profile and aims. It agrees that the merger of a hardware and software systems MSc is a very natural choice given the technological trends and the increasing overlap between the two programmes. The merged MSc CESE provides students with the opportunity to work in a more interdisciplinary way, crossing the historical borders between hardware and software to work on both aspects of electronic systems. In discussions with the External Advisory Board (see below) the panel noted that the merger is fully supported by professional field representatives, who also see the added value of a merged MSc on the intersection between hardware and software.

Intended learning outcomes
The MSc CESE is closely collaborating with the two Embedded Systems programmes at the TU Eindhoven and the University of Twente. 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 three MScs jointly composed a domain-specific framework of reference (DSFR), and the corresponding Consolidated Requirements, describing the knowledge and skills required of all graduates of the programmes. In constructing this DSFR, the programmes analyzed a number of relevant international frameworks related to cyber-physical systems and 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 as often used by engineering programmes. The Consolidated Requirements of the DSFR are translated by each of the three MScs into a set of Intended Learning Outcomes (ILO's). Within this common core, the individual programmes are free to highlight certain aspects, such as the hardware/software intersection at TU Delft.

The ILOs of the MSc CESE are the result of an integration of the learning outcomes of the original master's ES and CE. The redesign of the ILOs was based on the synergy between ES and CE, as well as the design principle of the new 2022-2023 curriculum: the 'responsible engineer of the future'. According to this principle, future engineers should be able to identify, define, analyze and contribute constructively and responsibly to solve current and future complex societal challenges. The resulting ILOs list the academic and professional competencies and domain knowledge in seven final attainment goals. For the full list, see appendix 1.

The panel studied the DSFR and the intended learning outcomes of the programme. The DSFR describes a comprehensive overview of the field of Embedded Systems, using relevant international frameworks and benchmarks. As these describe both software and hardware aspects, they were valid to use for ES as well as CE aspects of the ILOs. The panel concludes that the programme 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. In studying the ILOs of the CE and ES in relation to the ILOs of the CESE, the panel concludes that the CESE ILOs successfully incorporated the core elements of its two predecessors, and introduced new integrative ILOs connecting the two former programmes. According to the panel, this allows for a smooth merger for current students, and highlights the added value of the new MSc CESE.

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 TU/e and UT. 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 at Eindhoven in the same cluster) 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. 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 panel concludes that the MSc CESE has formulated a relevant profile as a MSc on the intersection between hardware and software. It draws from the strengths of the former MScs ES and CE, and adds an integrative layer that fits the technological trends in electronic systems design. Its intended learning outcomes reflect the goals of both former programmes as well as the connection between these, and are formulated on an academic master's level. They 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. Regarding the collaboration between the three universities, 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 CESE was launched in 2022-2023 as a merged and updated version of the curricula of the ES and CE programmes. It was initially adopted by both ES and CE simultaneously, and is offered under the CESE flag per 2023-2024. Pre-2022, both curricula already had a significant number of shared courses in the specialization and electives. This means that the merged curriculum could largely be constructed from existing courses, without radically departing from the old curricula. The CESE curriculum is provided in appendix 2.

The CESE curriculum consists of core courses (45 EC), specialization and elective courses (30 EC) and the thesis project (45 EC).

- The *core courses* are divided into common core courses (20 EC), a homologation course (5 EC) and integration sets (20 EC). Four common core courses introduce students to the fundamentals in computer and embedded systems engineering. Students follow a homologation course in either Hardware Fundamentals (for BSc Computer Science graduates) or Software Fundamentals (for BSc Electrical Engineering graduates). The integration sets are two sets consisting of an in-depth theoretical course coupled to a related project course (flagship projects).
- In the *specialization and elective courses*, students choose elective courses related to one out of four specializations (Computer Architecture, Networking, Software or Control). A maximum of 15 EC of this elective space is free: students can spend it on courses outside the CESE curriculum if they desire to do so. Examples are sets of courses related to entrepreneurship, quantum computing, AI or sustainability, an international exchange programme, an interdisciplinary project or an internship. The internship is aimed at applying knowledge in a professional context, and developing professional skills. Students are supervised by an academic staff member, with daily supervision provided by an external supervisor. In all cases, the Board of Examiners has to approve of the curriculum choices.
- The *thesis project* is an individual research project performed under supervision of a staff member of one of the research groups associated with the programme. It is usually carried out as part of a larger research project within the group, and accompanied by a literature survey.

The panel studied the curriculum of the programme, as well as the content of a number of courses, and discussed these with various MSc representatives during the visit. It concludes that the CESE curriculum is well-designed and covers all the ILOs of the programme, as demonstrated in a mapping of ILOs and courses provided to the panel. This also answers to the recommendations of the previous ES accreditation committee to revisit this to enhance alignment. The curriculum takes the core elements of the ES and CE curricula into account, while introducing new integrative elements. As a result, the core courses have been expanded from five in the original two MScs to nine in the current curriculum. The specialization and elective courses as well as the thesis project provide opportunities to tailor the curriculum to individual preferences

for broadening or specialization. The panel learnt that some students feel that the CESE curriculum has less flexibility than the previous curricula, and that they would prefer fewer core courses. The panel recommends evaluating the curriculum when the first cohort of students nears completion of the programme, and make adaptations if necessary.

Didactic approach
The didactic approach of CESE is based on the concept of the 'responsible engineer of the future' of the TU Delft. According to this concept, future engineers should not only have state-of-the-art disciplinary knowledge, but also societal awareness and ethical intelligence. Associated teaching concepts include developing a professional attitude and working in teams on hands-on projects related to real-world problems. This is most apparent in the flagship projects in the integration sets, where student teams design a high-tech system. Due to the relatively small-scale character of the programme, this can be combined with frequent teacher-student interaction in interactive lectures and lab sessions. The graduation projects are organized with a master-apprentice approach, where students work on a project in close collaboration with their supervisor. The MSc CESE is offered in English, since a large part of graduates of the programme will be active in an international industrial or academic context.

The panel is positive on the MSc's didactic approach, and recognizes this in the design of the curriculum. There are many opportunities for teamwork, both disciplinary and interdisciplinary. The panel learnt that these opportunities often also include projects where students from different MSc progammes are deliberately mixed. The panel thinks that this is a good method to teach students the professional skills they later need in daily practice, and apply their knowledge and skills in interdisciplinary settings. It learnt with appreciation that students value the teaching methods used in the programme, the interactive nature of the courses and the close collaboration with teaching staff members. According to the panel, 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.

The panel noted that the programme has taken the opportunity provided by the recent merger to finetune the new curriculum based on previous experiences and insights, keeping best practices and making improvements where necessary. An example of this is the strengthening of skills education. The new Effective and Responsible Engineering course is fully dedicated to academic and professional skills, including ethical and societal considerations of engineering. Furthermore, the programme management is planning a further constructive alignment exercise to also highlight the skills education in other courses, and construct a skills learning pathway throughout the curriculum. The panel is very positive on this development, including the addition of reflection on ethics and societal aspects to the curriculum, which is in line with the recommendations of the previous CE accreditation committee. It encourages the programme to continue the construction of the skills learning pathway and complete this promising curriculum design.

Another element that was changed in the new curriculum is the change in programming language from C to Rust. Where C was traditionally the most prominent language in electronic systems design, Rust is a relative newcomer explicitly designed for embedded systems development, and is currently gaining momentum in the academic world and increasingly in industry. The panel is very positive on this bold choice, and thinks that it shows that the programme is prepared to lead rather than follow. The External Advisory Board confirmed to the panel that they share this opinion, and hope that graduates of the programme can contribute to an envisioned transition to Rust in industry. The panel therefore supports this choice, although with the advice to closely evaluate the effects in consultation with students and alumni.

Guidance and feasibility

At the start of the programme, each student is assigned a student mentor, a second-year MSc student who helps students with onboarding and getting familiar with the TU Delft if they are new to the university. All student mentors are trained before starting their mentorship and guided by one of the academic counsellors. The master coordinator helps students with individual curriculum choices and to maintain a coherent curriculum. Further guidance in the programme is available in the form of quarterly Master Information Meetings where the master coordinator and programme director provide information about the programme and upcoming courses.

The panel appreciates the student guidance in the programme, and learnt that students are generally positive on the support and personal guidance they receive. Through the core courses, they are able to form a community of CESE students, and additionally feel part of a broader community due to the interdisciplinary courses with other MScs. The master coordinator plays an important role in monitoring the progress and well-being of students, and is available to help students with any issues they might have. Students also generally appreciate the student mentoring, although they mention that the nature of this mentoring strongly depends on the individual mentor. The panel recommends investigating whether the common starting points for student mentoring need strengthening.

Any gaps in pre-knowledge are addressed through the homologation courses at the start of the curriculum for students with a BSc in Computer Science or Electrical Engineering. Students with other backgrounds admissible to the programme are required to follow a bridging programme prior to entering the MSc. In addition, some courses start with a first session catching up on pre-knowledge, before covering the actual content of the course. The panel found that homologation is usually successful. Students feel well-prepared upon entering the programme, although some mention that they initially experienced the courses as very challenging. With the recent curriculum change, the programme is carefully monitoring any new gaps in pre-knowledge that might arise from the merger. Several new courses organize student panel sessions to ask for student input on their general impression of the course, including the alignment with the previous courses and BSc education. The panel appreciates this, and thinks that this is a good way to safeguard the feasibility of the new curriculum.

Regarding the issue raised by students that courses can be very challenging, the panel recommends a further check of the homologation courses as well as the study load of courses. This could for instance be done by mapping the prerequisites of each course in relation to the other curriculum components, and use this to fine-tune the homologation courses. Furthermore, a general set of extra course materials could be made available to students that wish to catch up on specific knowledge or skills by their own initiative. Regarding the student panel sessions for new courses, the panel thinks that this way of collecting student feedback might even be implemented in a more permanent way for all (core) courses. The panel learnt from students that they would like some more information on how their feedback contributed to the improvement of courses; it recommends finding a way to provide students with this.

The study duration in the MSc CESE is relatively long. Roughly 25% of students complete the programme within 2,5 years, whereas half of students take three years or longer. The programme management took the redesign of the curriculum as a starting point to tackle a number of known issues related to study duration. In the original two programmes, students tend to get delayed in the course work in the first part of the curriculum as well as the graduation project. The course-related delays were addressed by providing more structure to the curriculum in the form of pre-selected specialization packages. To limit the duration of the graduation projects, the programme has introduced a monitoring system that helps students stick to their planning and deadlines. The interviews with students and alumni confirmed to the panel that the curriculum

is feasible on principle, but that choosing and scheduling electives as well as the thesis project is a major source of study delay. It also discovered that students sometimes take extra electives and courses to take the most out of their studies, or change their preferences over the course of the curriculum, taking the associated delay for granted. The panel appreciates that the programme management is aware of the issues, and takes measures to tackle them. It thinks that the new curriculum with a more structured elective space will help students make more effective choices, and the monitoring system will help students and supervisors stick to thesis deadlines. It learnt that this system could also be used to monitor course progression, which the panel thinks would be a valuable addition to the toolkit of the programme management as well. Overall, the panel thinks that the curriculum is feasible, and that the programme is making good progress to limit the study duration of students.

Teaching staff

The teaching staff of the programme is associated with the Faculty EEMCS, and consists of active researchers in fields relevant to the programme. Their own research activities play a major role in the curriculum, especially in the graduation and flagship projects related to challenges that often originate from the academic or industrial network of the teaching staff. 53% of the teaching staff is in possession of the University Teaching Qualification (UTQ) or in the process of obtaining this. Of the remaining staff members, the majority has a diploma similar to UTQ from another institution or dispensation due to many years of teaching experience. Furthermore, all lecturers are required to be proficient in English on C1 level minimum.

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 relevant research expertise in the field covered by the programme, and brings this into the curriculum in the courses as well as the flagship and thesis projects. The panel noted from the interviews that the teaching staff members are enthusiastic and appreciated by students for their approachability, knowledge and dedication to strive for excellence in teaching.

As is often the case in academia, teaching staff members sometimes experience a generally high workload. This issue is most prominent for the more junior staff members, who need more time to set up courses. To alleviate their workload, the panel learnt with appreciation that courses are usually organized in collaboration between a junior and a senior staff member, and that this collaboration also functions as a coaching trajectory. Furthermore, the teaching staff members reported to the panel that they were generally satisfied with the current workload related to the CESE programme.

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 curriculum of the MSc Embedded Systems is well-designed, covers all ILOs of the programme and includes the core elements of both the MSc ES and CE, as well as new integrative elements. There is a good balance between core, specialization and elective courses in the programme. Moreover, there are sufficient elective elements to help students effectively compose their curriculum. The panel appreciates the didactic approach of the programme, which pays ample attention to interdisciplinary work, interactive teaching methods and close collaboration between students and staff members. Skills education,

including attention to ethical and societal aspects of engineering, has been strengthened in the new curriculum. The panel supports the development of a skills learning pathway throughout the curriculum. The choice for English as language of instruction is appropriate, and fits the very international nature of the academic and professional field. The choice for Rust as programming language in the programme is appreciated by the panel, and shows that he programme is prepared to take a leading role in the field. In general, the panel recommends monitoring the implementation of the new curriculum choices in consultation with students and alumni, and make adaptations where necessary.

Student support and guidance are well-implemented in the programme. Students feel supported and part of a broader community. Some students feel that the courses are very challenging; the panel recommends investigating whether any changes are necessary to either the homologation courses or study load associated with courses to address this. The curriculum is feasible, although study duration is relatively long. The main reason is that students often take longer to make curriculum choices and complete their thesis projects. Both issues are currently being addressed by the programme through a more structured curriculum and by monitoring thesis progress. The panel supports this, and encourages the programme to continue these efforts. The teaching staff is appreciated by students and well-qualified to teach in the programme. Sufficient attention is paid to the challenges of high workload of staff members, for instance through co-development of courses. The staff is appreciated by students for their approachability, knowledge and dedication to strive for excellence in teaching.

Conclusion

The panel concludes 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

The assessment policy of CESE is founded in a newly created framework, that was developed based on the programme-specific assessment policies of the ES and CE programmes. It details rules and procedures for valid, reliable and transparent assessment. Examples are specification of assessment methods for each course in the study guide, sharing rubrics before assignments and peer-review based construction of exams by the teaching staff. The faculty has a dedicated assessment expert that can help teaching staff members create testing matrices for their course, and assists the Board of Examiners in evaluating exams.

Assessment in CESE consists of written exams for theoretical courses, written assignments, lab assignments and project work with reports, presentations and design documents. Most courses use a combination of assessment methods, with a weighted average as the final grade. The optional internship is assessed as pass/fail based on an internship report describing the (scientific) results of a small project carried out within the internship company, and a reflection report describing the personal development of the student. This is assessed by the internal TU Delft supervisor, based on advice by the company supervisor.

The programme shares a Board of Examiners with other programmes in the Faculty EEMCS. Programme-specific responsibilities such as handling requests and safeguarding the quality of course and thesis assessment are mandated to subcommittees. The MSc ES was part of the subcommittee Computer Science

and Embedded Systems, and the MSc CE of the subcommittee Electrical Engineering and Computer Engineering. Per September 2023, a new subcommittee specifically for the MSc CESE will be implemented, composed of the members responsible for ES and CE in the current two subcommittees. The subcommittees handle programme-specific quality assurance of assessment. This includes regular checks on the assessment of courses, as well as an annual sample of master's theses.

The panel reviewed the assessment policy and procedures of the MSc CESE, and interviewed the Board of Examiners. It concludes that the programme has a solid system of assessment with an appropriate variety of assessment methods and assessment policies that safeguard the reliability, validity and transparency of assessment. It noted that the constructive alignment of the assessment in the new curriculum is still somewhat work in progress. The Board of Studies plans to create an overview of all assessment methods in the courses by 2023-2024 in order to verify the variety of assessment methods in the curriculum. The panel supports this, and suggests to connect this exercise to the creation of the skills learning trajectory (see above) with regard to skills assessment.

The Board of Examiners 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. The panel appreciates the introduction of a new subcommittee for CESE as the merger between CE and ES is officially completed per September 2023. During the interview, the panel and Board 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 Board could reach out to the Boards of Examiners of the two Embedded Systems programmes in Twente and Eindhoven to discuss what the domain-specific consequences of these policies could be.

Thesis assessment
The graduation project is assessed by a thesis committee consisting of a chair (a full or associate EEMCS professor), another staff member as second examiner, possibly supplemented with a third examiner or external expert. The latter is not a formal examiner, but can participate in the committee deliberations. After a public thesis defense and examination of the candidate, the committee decides through consensus on the final mark based on the quality of the thesis report, as well as the presentation and defense. To support consistency, the faculty used an assessment rubric to determine the grade. As thesis assessment is organized on a faculty level, the assessment procedures of ES and CE were already aligned.

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 and the way in which they decide upon and substantiate the grades add to the reliability and validity of thesis assessment. The forms and rubrics are generally used in an insightful way, with attention paid 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, especially regarding theses on the higher or lower end of the spectrum. The panel learnt during the site visit that the programme is planning on changing the form to oblige graduation committees to include more qualitative feedback before the forms are accepted.

One of the 15 theses that the panel studied was on a topic that was far removed from embedded systems, the MSc that the student graduated from. From the explanation on the assessment form, the panel understood that this student graduated in special circumstances, but further substantiation was lacking. Additional information provided by the programme showed that the student was allowed by the Board of Examiners to graduate with a 'free curriculum' as allowed by the Higher Education and Research Act (WHW)

article 7.3.j, combining the courses of the MSc ES with that of a business MSc, and graduating with a business-related research project. After discussions with the programme management and the Board of Examiners, the panel is convinced that the Board acted in good faith by allowing this. However, as graduation in a free curriculum is seldom used, jurisprudence on the extent to which a student is allowed to deviate from a programme's learning objectives while still receiving a diploma of that programme is lacking. The panel recommends the development on further policies on this on the level of the TU Delft.

To add to this issue, the panel also found that the student in question ultimately delivered a substandard thesis, but still got a minimum passing grade. The programme management explained that the student passed all courses, and that the supervisors were ultimately convinced that the student had the capabilities required by the programme, even though the final project was lacking. In hindsight, the programme management agrees with the observation of the panel that the examiners were too lenient in their well-intended efforts to take the difficult personal circumstances of the student into account in the assessment of the thesis. The panel concludes that this was one unfortunate incident, and there was no indication at all of any structural issues within the thesis assessment of the programme. Both the quality and assessment of the other 14 theses, which included a range of higher to lower graded theses, were found by the panel to be up to standard. The Board of Examiners (which found that this thesis happened to not be included in that year's random sample) immediately announced further measures to decrease the chance that similar future cases would escape their control mechanisms. This means structurally including all theses on the very low (and very high) end of the spectrum in their annual sampling, and requiring supervisors to announce potential low-scoring theses to the Board so that they can proactively monitor the assessment procedures. The panel supports these measures, and adds a recommendation to pay extra attention to the substantiation of grades and providing context on the assessment form to help understand the grade, especially in special circumstances like this. In the end, the panel is very positive on the way the programme and Board took up this issue, and has full confidence that the programme will do everything in its power to prevent this from happening again.

Considerations

The panel concludes that the assessment system of the programme is solid, with an appropriate variation of assessment methods and policies. The panel supports the planned constructive alignment of assessment in the new curriculum, and suggests connecting this to the creation of the skills learning pathway for skills assessment. The Board of Examiners is proactive and in control of assessment quality assurance with regular checks and sampling. Thesis assessment is appropriate, with solid assessment rules and procedures, and an insightful form and associated rubrics. Even though one thesis was found to be below the standard, the panel is convinced that there are no structural issues regarding thesis assessment. The thesis was graded under special circumstances that are unlikely to reoccur. The panel was further reassured by the additional control mechanisms announced by the Board of Examiners to prevent another such incident. The panel also advises to further enforce more extensive qualitative feedback on the assessment forms, especially in the case of particular circumstances.

Conclusion

The panel concludes that the programme meets standard 3.

Standard 4. Achieved learning outcomes

The programme demonstrates that the intended learning outcomes are achieved.

Findings

In order to determine the exit level of students, the panel studied 8 recent theses of the MSc ES and 7 theses of the MSc CE, taking care that a variety of grades and topics was covered. It concludes that 14 out of 15 theses convincingly showed that students achieve the intended learning outcomes of the programme. The panel was impressed by the high quality of the work. Students show an ability to conduct good scientific research and are able to systematically explain this to the reader. They are able to design and implement embedded systems, using state-of-the-art methods. One of the theses that the panel studied did not meet the level and content that can be expected for a graduate of this programme. After extensive discussion with programme representatives, the panel concluded that this thesis is an outlier and not representative for the general high level of graduates. The full discussion on this issue can be found in the Findings of standard 3. The panel learnt that 35 MSc students co-authored in publications related to thesis projects in the past six years. The panel considers this to be a further proof of the high level of the programme's graduates.

Graduates of the programme often find a position in high-tech and ICT companies, with approximately 5% pursuing a PhD trajectory. Alumni report to be satisfied with the education, and indicated in a recent alumni survey to be very satisfied with the programme in general, and the way it prepared them for their further career. The External Advisory Board confirmed that graduates of the programme are in high demand and generally valued. The panel concludes that this demonstrates the achievement of the intended learning outcomes, and the appreciation of graduates by the field.

Considerations

The quality of the theses as well as the job prospectives and satisfaction of the alumni convinced the panel that students of the MSc CESE achieve the intended learning outcomes.

Conclusion

The panel concludes that the programme meets standard 4.

General conclusion

The panel's assessment of the MSc Computer and Embedded-Systems Engineering is positive.

Development points

1. Realize the plans for the creation of a skills learning pathway and the constructive alignment of assessment throughout the new curriculum.

2. Keep monitoring the implementation of the design choices made in the new curriculum in consultation with students and alumni, and make adaptations where necessary. This includes the amount of core courses vs elective space, the use of the Rust programming language, the course workload for students and student progress throughout the curriculum.

3. Enforce more extensive qualitative feedback on the thesis assessment forms, especially in the case of special circumstances, and implement the planned tighter control mechanisms on low-scoring theses by the Board of Examiners.

Appendix 1. Intended learning outcomes

1. Scientific discipline: The graduate has sufficient knowledge, skills and a clear understanding of computer and embedded-systems engineering, enabling the graduate to perform independent professional and scientific activities in this field at an academic level. This consists of:
    a. an all-embracing view on computer engineering and embedded systems, and mastery of at least one specialisation area within this field (such as Software, Computer Architecture, Networking or Control). In particular, the design and their application in systems of various sizes, including their evolution over time, demonstrated by a comprehensive approach in system design
    b. the capability to analyse the functional behaviour of complex computer architectures and embedded systems in a structural way, using appropriate abstractions
    c. the ability to describe and evaluate the non-functional aspects of computation platforms(hardware and software) and the surrounding system (sensors and actuators), e.g. resource boundedness and dependability
    d. a thorough knowledge of state-of-the-art and emerging methods and technologies for computer and embedded-systems engineering such as requirements engineering, hardware-software integration, performance modelling and analysis, validation and testing, computer architectures, computer arithmetic, compiler construction and code generation.

2. Doing research: The graduate is able to conduct research independently that contributes to the development of scientific knowledge about the application of computer and embedded-systems engineering to address complex problems.

3. Designing: The graduate is able to design computer architectures and embedded systems independently that satisfy functional and non-functional requirements, taking into account the performance of the system during its lifetime.

4. Scientific approach: The graduate has a scientific approach to complex problems and ideas, i.e., the graduate can define a research or engineering problem, choose an appropriate approach, and complete that project.

5. Intellectual skills: The graduate has intellectual skills befitting an academic graduate. This includes:
    a. the ability to reflect critically, reason and form opinions,
    b. the capability to continue their studies in a manner that is largely self-directed, self-regulated and self-motivated (lifelong learning).

6. Cooperating and communicating: The graduate is capable of working in interdisciplinary teams, performing research or design activities and communicating easily in English, both in writing and orally. This includes:
    a. the attitude to include other disciplines or involve practitioners of these disciplines in their work, where necessary
    b. the ability to collaborate in multi-disciplinary settings, where necessary
    c. the ability to communicate the results of their findings, thinking and decision-making processes at an international level.

7. Temporal and social context: The graduate is aware of actions and consequences related to these actions on society and vice versa. This includes:
    a. a. being aware of the temporal, social and ethical context of science and technology (comprehension and analysis) and being able to integrate this context responsibly in their scientific work
    b. b. the ability to appraise costs and environmental issues in order to make optimal use of available resources.

Appendix 2. Programme curriculum

First Year (60 EC)			
1st quarter	2nd quarter	3rd quarter	4th quarter
Adv. Computing Systems 5EC	Software Systems 5EC	Specialisation 5EC	Effective & Responsible Engineering 5EC
Systems Engineering 5 EC	Real-Time Systems 5EC	Embedded Systems Lab 5EC	Specialisation 5EC
Software Fundamentals / Hardware Fundamentals 5EC	Specialisation 5EC	Computer Arithmetic 5EC	Processor Design Project 5EC
Second Year (60 EC)			
1st quarter	2nd quarter	3rd quarter	4th quarter
Joint interdisciplinary project Internship, or set of elective courses (e.g. entrepreneurship, quantum, AI, sustainability)	Thesis Project (45EC)		

Appendix 3. Programme of the site visit

Mon 8 May

16.00-19.00 Panel preparation

Tue 9 May

112.00-12:45 **General session: 3TU Collaboration** (during UT site visit)

Wed 10 May

12.00-12:45 **General session: Industrial Advisory Board** (during TU/e site visit)

Thu 11 May

08.30-09.00 Preparation
09.00-09.45 **Management TU Delft**
10.00-10.45 **Students and alumni TU Delft**
11.00-11.45 **Teaching staff TU Delft**
12.00-12:45 **Development session: Future of the CESE programme**
12.45-13.30 Lunch
13.30-14.00 **Board of Examiners TU Delft**
14.00-14.30 Internal panel session
14.30-15.00 **Concluding session management TU Delft**
15.00-16.15 Internal panel session
16.15-16.45 **Feedback and conclusion**

Appendix 4. Materials

Prior to the site visit, the panel studied 15 theses of the programme. 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 CESE,
- Intended Learning Outcomes ES and CE (former)
- Curriculum CESE
- Curricula ES and CE (former)
- Documentation planning-neutral conversion CE and ES into CESE
- Intake and success rates of students
- Information External Advisory Board
- Domain-Specific Frame of Reference (DSFR)
- Program and Examination Regulations
- Assessment policy
- Alumni survey results
- Peer-reviewed CESE master student publications
- Reports of examination committee and programme committee
- Staff of the programme
- Examples of course materials