Learning outcomes of the specialisations of de Electrical Engineering master's programme

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Motivation

At this moment the learning outcomes of the Electrical Engineering master's programme in Twente are defined without explicitly specifying its technical content. This is because the programme does not have technical core courses. Instead, the students choose a specialisation at the very beginning of the programme. Each specialisation has its own core programme of compulsory courses.

In the latest *Critical Reflection Master Electrical Engineering University of Twente* [1] the learning outcomes of the programme are compared with the learning outcomes deduced in the *Domain Specific Frame of Reference* (DSFR) [2]. The DSFR has been written by a committee from the three Technical Universities in Eindhoven, Twente and Delft. It contains an inventory of the Electrical Engineering domain, including subdomains and application fields. The document contains two tables containing learning outcomes of the bachelor's and the master's programme respectively. The table for the bachelor's programme contains technical and scientific topics that should occur in a bachelor's programme. However in the table for the master's programme (table 2) only general descriptions are given of the topics that should occur in a master's programme. A master should have:

- an in-depth knowledge in advanced fundamentals of mathematics and natural sciences,
- an in-depth knowledge in advanced subject-specific fundamentals of electrical engineering,
- an in-depth knowledge in one of the mentioned primary fields of application based on subject-specific fundamentals.

In the Critical Reflection the learning outcomes of the master's programme are shown to satisfy the requirements from the DSFR as described above (Standard 1, table 1.3). However, no specifications are given of the required knowledge for each specialisation separately. Therefore we cannot check that the course programme of a specialisation gives a valid coverage of the subdomain of the specialisation. We have to be confident that the concerned staff members made sound choices for the courses in the specialisation programme.

This makes the programme vulnerable during a visitation, because these choices are not justified in an official document (like the Critical Reflection). Also the examination board does not have clear criteria to assess the validity of the course programme of a candidate.

In this document we will propose a framework to specify learning outcomes of the Electrical Engineering master's programme taking into account the learning outcomes defining the specialisation. We first propose a new set of learning outcomes in which we identify the learning outcomes, being specialisation dependent. Then as an example we sketch how these learning outcomes can be made explicit for the specialisation Integrated Circuit Design.

Final purpose of the definition of the learning outcomes of the EE-specialisations

Here we explain how we can see the activity of defining learning purposes for the EE-specialisations within the framework of assessment. In Figure 1 the *quality pyramid of contemporary assessment and evaluation* is sketched. The translation into English is according to [3].

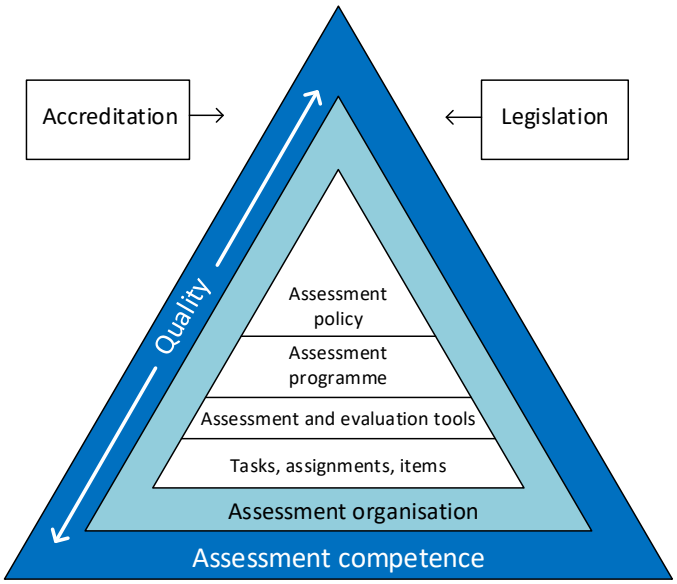

Figure 1 The quality Pyramid of contemporary assessment and evaluation

The assessment programme contains all tests necessary to test the learning outcomes of a study programme. Currently the assessment plan for the Electrical Engineering master's programme is incomplete, because no assessment of the learning outcomes of the specialisations is mentioned. The approach adopted in this document contains the following steps:

- to define explicit learning outcomes for each specialisation
- to assemble a programme of education units such that the learning outcomes of these units cover the learning outcomes of the specialisation.
- to obtain the assessment programme of the specialisation by combining the assessment programmes of its educational units.
- to obtain the assessment programme of the master's programme by combining the assessment programme of a specialisation with the common assessment parts of the master's programme.

A framework for the assessment programme for Electrical Engineering has been elaborated previously by me during the SKE-course 2019 [4](section 3, in Dutch).

The final purpose of obtaining learning outcomes for the specialisations is therefore to complete the assessment plan for the master's programme, including the specialisations.

Discussions

The idea to specify learning outcomes for the Electrical Engineering specialisations has been discussed with the Director of Education of the programme, Anne Johan Annema, and with the chair of the Examination Board, Eric Klumperink. It was agreed that this approach is feasible. Formulating the ICD learning purposes has been discussed with Eric Klumperink, who is the lecturer of one of the compulsory courses of the specialisation, but the results given in this document are partially my own interpretation. All results will need further discussion to arrive at a final form.

Background and Approach

The Electrical Engineering master's programme educates students in one of the specialisations offered by the research groups at the Department of Electrical Engineering at the University of Twente. The core of a specialisation is the research area covered by the research group that defined the specialisation.

The setup of the EE-programme is as follows:

First year: courses		Second year: practical work	
Topic	**EC**	**Topic**	**EC**
Compulsory specialisation courses	20	Internship	20
Philosophy and societal courses	5 or 10	Master's thesis final project	40
Advanced electives	35 or 30		
Total	60	Total	60

The compulsory specialisation courses have been defined for each specialisation separately. Depending on the specialisation they are completely fixed, or some of them are chosen from a limited set based on the research interests of the student (within the specialisation).

The advanced electives will be proposed by the student. They will partially deepen his knowledge of specialisation topics. However some of them also may be related to adjacent specialisations, bringing more broadness in the student's course programme.

The purpose of this document is to present a framework for the definition of learning outcomes for the Electrical Engineering master's programme, which will include learning outcomes on the level of the specialisation. We will address the following topics:

1. Defining new learning outcomes for the programme with slots to be filled in for each specialisation separately.
2. Define learning purposes for one of the specialisations as an example.
3. Relate the learning outcomes of the compulsory courses to the learning outcomes of the specialisation (only an indication of the process).

New learning outcomes of the programme

In the general practice of the Dutch engineering programmes, the learning purposes are obtained from two sources:

1. The Meijers criteria are used to obtain general competences that every engineer should have, without specification of the specific content of the programme. As such they have been adopted by the 4TU-universities (Delft, Eindhoven, Twente, Wageningen).
2. The Domain Specific Frame of Reference describes the engineering field for which the programme educates and defines specific learning purposes for this field. It has been written as a common document by the Electrical Engineering Departments in Eindhoven, Twente and Delft.

The Learning Outcomes of the programme can be obtained by merging the Learning Outcomes obtained above. We have decided to rewrite our learning outcomes to get a more direct connection between the learning outcomes of the programme and the requirements formulated by the Meijers criteria and the DSFR. Also we can explicitly identify the learning outcomes, defined in the DSFR that should be filled in for each specialisation separately.

We have chosen to maintain the setup of the Meijers Criteria and to fill in learning outcomes from the DSFR at the appropriate places. The result of this exercise should be a set of Intended Learning Outcomes, satisfying the Meijers criteria and the Learning Outcomes from the DSFR.

The merged learning outcomes have been obtained from the general Meijers Criteria mentioned in the DSFR document (Section 9) and the domain specific requirements for Electrical Engineering master graduates, mentioned in table 2 of the same document. The merge is shown in the section

below. The learning outcomes from the DSFR have been divided over the corresponding Meijers Criteria. The learning outcomes that will have to be filled in in a specialisation dependent way, have been written in italics.

In this document, only the main learning outcomes 1 to 7 of the Meijers criteria are given. The subcategories a, b, etc. have been omitted and may have to be considered later. As we can see in the table, the learning outcomes from the DSFR are partially specialisation independent and may have to be merged with corresponding learning outcomes from the Meijers Criteria. This may become a tedious exercise.

Merged learning outcomes of the MSc-programme Electrical Engineering

Meijers 1

Is competent in one or more scientific disciplines

DSFR 1-3: knowledge and understanding

- *have an in-depth knowledge in advanced fundamentals of mathematics and natural sciences*
- *have in-depth knowledge in advanced subject-specific fundamentals of electrical engineering*
- *have in-depth knowledge in one of the mentioned primary fields of application based on subject-specific fundamentals*

DSFR 7: engineering practice and product development

- *judge applicable methods and their limits*

Meijers 2

Is competent in doing research

DSFR 4: engineering analysis

- *can evaluate new complex modelling, measuring, design and test methods concerning their relevance, effectiveness and efficiency and can develop independently new methods*

DSFR 6: investigations and assessment

- can develop suitable methods to make concepts, do and evaluate detailed research concerning technical topics

DSFR 7: engineering practice and product development

- (also Meijers 3) use and to develop their knowledge and skills in order to gain practical power for the solution of problems, for the organizing of research and the development of systems and processes

Meijers 3

Is competent in designing

DSFR 5: engineering design

- *have specific skills for the design, development and operation of complex technical systems and services, thereby they*
- *(also Meijers 7) are capable to assembly the best components of these systems optimally as well as to evaluate the interaction of the systems with their environment, (taking into account technical, social, economical and ecological aspects)*

DSFR 7: engineering practice and product development

- (also Meijers 2) use and to develop their knowledge and skills in order to gain practical power for the solution of problems, for the organizing of research and the development of systems and processes

Meijers 4

Is able to work according to a scientific approach

DSFR 7: engineering practice and product development

- classify knowledge methodically in different areas, to combine information elements systematically, and to handle the phenomena of complexity

DSFR 8: Transferable skills

- take over responsibility for scientific contributions to professional knowledge and to professional practice

Meijers 5

Has basic intellectual skills

DSFR 7: engineering practice and product development

- familiarize quickly, methodically and systematically with new and unknown tasks

DSFR 8: Transferable skills

- control and organise complex, changing inter-relations of work and learning which require new strategic approaches
- check the strategic capacity of teams

Meijers 6

Is competent in co-operating and communicating

Meijers 7

Takes account of the temporal and social context

DSFR 5: engineering design

- (also Meijers 3) are capable to assembly the best components of these systems optimally as well as to evaluate the interaction of the systems with their environment, **taking into account technical, social, economical and ecological aspects**

DSFR 7: engineering practice and product development

- reflect systematically (on) non-technical implications of engineering work and to integrate the results responsibly in their actions
- to develop marketable products for the global market

An example: the specialisation Integrated Circuit Design

The description given in this paragraph is based on a discussion with Eric Klumperink, associate professor in the group. More discussions will have to be necessary to obtain a final result.

Profile of the ICD-specialisation

According to the current description of the specialisation we have [5]:

“In the Integrated Circuit Design group (ICD-group) we do research on integrated transceivers in CMOS technology. This includes transmitters and receivers for wireless and wireline communication

systems. We develop clever IC design techniques to realize portable, fast and energy efficient communication systems. Current projects are in the field of frequency synthesisers, radio frontends, RF beamforming and cognitive radio."

Note: This is a description of the research in the group, while we would like to have a description of the field of research/design, for which the student will be educated. Some adaptations will therefore be necessary to check the learning outcomes.

General competences	**ICD**
Meijers 1 Is competent in one or more scientific disciplines **DSFR 1-3: knowledge and understanding**	
have an in-depth knowledge in advanced fundamentals of mathematics and natural sciences	• *calculus, linear algebra, differential equations* • *signals and systems* • *probability, random signals and noise* • *electromagnetic fields and waves* • *quantum and semiconductor physics*
have in-depth knowledge in advanced subject-specific fundamentals of electrical engineering	• *analogue and mixed signal processing* • *analysis and synthesis of (micro-) electronic circuits* • *semiconductor device operation and modeling* • *transduction and mechanical devices*
have in-depth knowledge in one of the mentioned primary fields of application based on subject-specific fundamentals	• *computer systems and computer architectures, including dedicated hardware* • *radio frequency applications* • *audio/video transmission* • *sensing and sensors* • *AD-conversion*
DSFR 7: engineering practice and product development	
judge applicable methods and their limits	*know how to realise electronic functions using IC-technologies*
Meijers 2 Is competent in doing research **DSFR 4: engineering analysis**	
can evaluate new complex modelling, measuring, design and test methods concerning their relevance, effectiveness and efficiency and can develop independently new methods	*Can analyse available techniques for the realisation of ICs for analogue and mixed signal processing, based on background knowledge about the available IC-technologies and the requirements obtained from the input and output signal properties and can develop independently new IC architectures.*

Meijers 3 Is competent in designing **DSFR 5: engineering design**	
have specific skills for the design, development and operation of complex technical systems and services, thereby they are capable to assembly the best components of these systems optimally as well as to evaluate the interaction of the systems with their environment, (taking into account technical, social, economical and ecological aspects)	*Have specific skills for the design of analogue and mixed signal processing circuits, based on appropriate design software packages. Optimisation of the design by using background knowledge about the available IC-technologies and the requirements obtained from the input and output signal properties. Specification of the input and output signal properties from sensor and actuator properties.*

Note

Especially in the knowledge and understanding part, learning outcomes have been included that many students will have covered during the bachelor's programme. Doing this makes it more clear which competences graduates from the specialisation have. Also it illustrates that the learning outcomes can be divided into topics that will be actually learned during the programme and requirements regarding the prior knowledge that students must have when entering the programme.

Creating a course programme that leads to the required learning outcomes

Because of lack of time we cannot explicitly carry out the process announced in the title of this section. However we can discuss some aspects of the approach. We distinguish the following steps:

1. Separate the prior knowledge from the knowledge obtained during the programme.
2. Select the courses necessary to cover the learning outcomes to be obtained during the programme. This is a matter of comparing the learning outcomes of the courses with the learning outcomes of the programme.

At this moment, four courses are compulsory, two non-technical courses are also compulsory while the student proposes seven courses to complete the programme. In practice these electives will contribute to the learning purposes of the specialisation and therefore the process of choosing them will be supervised by a programme mentor. It can be discussed if this process of choosing electives should be somewhat more structured, to make this contribution more explicit.

Working plan

The final purpose of the activity that was started in this document is to obtain a sound assessment programme for the Electrical Engineering master's programme. In the table below we sketch what should be done to achieve this purpose. Also it is indicated which parties will be involved.

Activity	Involved gremia
Obtaining final learning outcomes and assembling the course programme for the ICD specialisation	EE programme management, ICD management
Finalising and adopting the model for the description of the Electrical Engineering master's programme.	EE programme management, Programme Committee for advice, Examination Board for advice.
Obtaining final learning outcomes and assembling the course programme for all specialisations	EE programme management, research group management of the specialisations
Finalising and adopting the description of the Electrical Engineering master's programme including all specialisations	EE programme management, Programme Committee for advice
Assemble an assessment programme for the EE master's programme	EE programme management, Examination Board for advice

Conclusion

We have proposed a framework for obtaining learning outcomes for the specialisations of the Electrical Engineering master's programme. The example of the ICD-specialisation should give a look and feel of how this process may work out. Although much work remains to be done, we believe that the approach is feasible. Also we believe that carrying out this process will lead to a better structured programme and that finally it will enable us to check in a better way that the students indeed learn what they should learn according to well defined learning outcomes.

References

[1] M. J. Bentum et.al., Critical Reflection Master Electrical Engineering, Enschede, 2016.

[2] Domain Specific Frame of Reference, Electrical Engineering, Delft, Eindhoven, Twente, 2016.

[3] HU Assessment Framework, Utrecht: HU University of Applied Sciences, 2017.

[4] M. J. Korsten, De situatie m.b.t. zorgen en borgen van de toetskwaliteit van de masteropleiding Electrical Engineering, Enschede, 2019.

[5] https://www.utwente.nl/en/mee/programme-information/Specialisations/icd/.