National Guidelines for Engineering Education

Towards the future

Revised Regulations relating to the National Curriculum Regulations for Engineering Education were passed by the Ministry of Education and Research on 3 February 2011, defining the national framework for Engineering Education. Together with the Regulations and accompanying notes, these Guidelines are to provide national standards and contribute to national coordination of study programmes and levels of programme options. The Guidelines also contain supplementary characteristics and indicators that ensure the quality of education its implementation. Where there are defined learning outcome descriptors in these Guidelines they are to be followed. The National Council for Technological Education, NRT is responsible updating these Guidelines.

June 2011

Written and approved by the National Council for Technological Education (NRT). *This English version of National Guidelines for Engineering Education (1st cycle) may differ from the authoritative version, which is in Norwegian. If so, the authoritative version is to be consulted.*

Introduction

Following the evaluation of Engineering Education in 2008 by the Norwegian Agency for Quality Assurance in Education (NOKUT) and the implementation of the National Curriculum Regulations for higher education, the Ministry of Education and Research (KD) has revised the National Curriculum for Engineering Education.

KD appointed a committee that to make proposals for a revised national curriculum Regulations and related national Guidelines. The vision for the Regulations and Guidelines were:

> *The engineer—socially aware, creative, and diligent, with the ability to actively contribute to challenges in the future.*

KD passed the revised Regulations defining the National Curriculum for Engineering Education on 3 February 2011. Along with the Regulations and notes, the Guidelines are to provide national standards and contribute to a national coordination of study programmes and levels of programme options. The Guidelines also contain supplementary characteristics and indicators that ensure the quality of education and its implementation. Where there are defined learning outcome descriptors in these Guidelines they are to be followed.

The Guidelines are also to ensure that the relevant institutions are able to carry out the Ministry's demands and expectations in terms of collaboration, division of labour, and academic focus.

This document is created by the National Council for Technological Education (NRT), and is a revision of the National Curriculum Regulations Committee Guidelines. NRT is responsible for updating these Guidelines.

Oslo, June 2011

National Council for Technological Education

1 Preface

> Vision:
>
> *The engineer—socially aware, creative, and diligent, with the ability to actively contribute to challenges in the future.*

The National Curriculum Regulations Committee has elaborated on this vision, describing the engineer of tomorrow:

> "*As an engineer, you are able to use both your analytical and creative skills to solve socially valuable technological problems. You will have to work innovatively, structurally, and diligently. You have to analyse, generate solutions, assess, determine, execute, and report – be a good entrepreneur. In addition to natural science and technological subjects, your linguistic skills are important, both written and oral, both in Norwegian and in foreign languages. Interacting systems are essential to the modern society, and you must thus be skilled at working independently as well as in teams with engineers from your discipline and from others, professionals from other fields, and in interdisciplinary teams. As an engineer, you will work with people, you will have ethical and environmental responsibilities and you will have a significant impact on society.*"

The revised National Curriculum provides a foundation for educating engineers with the above characteristics. Regulations relating to the National Curriculum for Engineering have formed the basis of these national Guidelines.

Engineering Education is an integrated education where separate components must be approached comprehensively. The purpose of such an approach is to create motivation, curiosity, and a comprehensive perspective of problems in engineering. Students should recognize the value of each educational component, their comprehensive relationship and how they can contribute to societal development. In addition to analytical orientation, such as being able to use mathematics as an analytical tool and recognize mathematical contexts, business and industry require systems analysis and synthesis from the engineers of today and tomorrow. The education is to contribute to self-realization and personal development for the students.

The challenge met by each institution when implementing these Guidelines is to create the engineering education of tomorrow. This includes highlighting the importance of environmental commitment, and enabling young people to realize themselves in their field of engineering.

The Ministry sent a letter regarding the revised Regulations for a National Curriculum for Engineering Education, including notes, on 4 February 2011. These Guidelines must be considered in relation to these documents. The revised National Curriculum is based on a nationally established qualifications framework, and meets areas for improvement identified by NOKUT in the Engineering Education evaluation from 2008.

Part one of the Assessment Report from NOKUT's Engineering Education evaluation includes 69 recommendations, as well as some recommendations outside the mandate of the evaluation. The Institution Report (part two) and the Scientific Report (part three) include additional recommendations, and the review is included in the End-User Report (part four).

The National Curriculum Regulations Committee's document "Reasons for Revised Regulations for the National Curriculum in Engineering," demonstrates how NOKUT's recommendations have been implemented and have established the basis for the approved curriculum.

Below are the levels of introduction to qualification-based education in relation to Engineering Education. This list illustrates implementation levels in terms of qualifications. These levels build on one another, and must be considered cohesively.

International Level
The European Qualifications Framework for Higher Education
The European Qualifications Framework (EQF, for all education)
National Level
The Norwegian Qualifications Framework for Higher Education, passed in 2009
The Norwegian Qualifications Framework for Lifelong Learning (NKR, from primary education to PhD)
Educational Level
National Curriculum Regulations for Engineering, 2011
Discipline Level
The Guidelines include learning outcome descriptors for these disciplines: Civil Engineering, Computer Engineering, Electrical Engineering, Chemical Engineering, and Mechanical Engineering
Study Programme and Programme Option Level
The institution's programme plan
Course Level
The institution's programme/course plan

The purpose of qualification-based education became apparent during the work on NKR[1]. The main reasons are:

- Arrange/motivate for lifelong learning
- Increase mobility for students and national/international careers
- Simplify approval of international qualifications
- Arrange for new (types of) qualifications
- Make qualifications more relevant
- Make qualifications more intelligible for the professional sectors, other educational institutions, and the general public

National Curriculum Regulations for Engineering corresponds with the approved national learning outcome descriptors for bachelor's degrees. There is a new demand for a National Curriculum for Engineering.

[1] One of the documents that demonstrates the purpose of NKR is Appendix 2 to KD's consultation letter regarding NKR dated 26 January 2011.

In this document, “qualification” denotes the sum of knowledge, skills, and general competencies describing the learning outcomes. The term “total learning outcome” is used interchangeably with “qualification.”

Implementing the revised National Curriculum for Engineering will be a significant challenge for each institution. The Regulations provide the overriding objectives for Engineering Education. In addition to the Guidelines, the ministry’s notes emphasize how the Regulations and their function should be reviewed. The national Guidelines are based on the Regulations and are to ensure national coordination of high academic quality Engineering Programmes. Such programmes are to be research-based, innovative, and professionally and internationally oriented.

2 Learning Outcomes (Section 2 in the Regulations)

The learning outcome descriptors for Engineering Education have been prescribed in the revised National Curriculum Regulations, Section 2. The Regulations describe the educational learning outcomes for candidates who have completed three years of Engineering Education (qualification). Based on the Regulations, the institutions must develop a set of learning outcome descriptors at study programme, programme option, and course levels. Learning outcome descriptors in the disciplines Civil Engineering, Computer Engineering, Electrical Engineering, Chemical Engineering, and Mechanical Engineering have been developed. Upon graduation, the institution will confirm that the required qualifications have been met. Courses in the study programmes are to illustrate that each qualification is reached, and performance assessments should be based on the grading scale.

Learning outcomes (qualification) are defined in the National Curriculum as:

- Knowledge
- Skills
- General competencies

The learning outcome descriptors as stated in the Regulation are specified on the following page. The abbreviations refer to each element that devises the requirements for knowledge, skills, and general competencies. LU-K-1 refers to the first learning outcome descriptor under knowledge; the other descriptors have been given a similar code. Appendix 2 elaborates on each descriptor with respect to the different requirements relevant to Engineering Education.

The ministry’s consultation letter regarding the National Curriculum Regulations for lifelong learning (NKR) highlights the meaning of the three concepts. **Knowledge** is an understanding of theories, facts, concepts, principles, and procedures related to a field, discipline, and/or careers. **Skills** denote the ability to apply knowledge to problem solving and executing tasks. There are several types of skills – cognitive, practical, creative, and communicative. **General competencies** refer to the ability to use knowledge and skills independently in various situations, demonstrating teamwork, responsibility, reflection, and critical thinking in academic and professional settings.

The fundamental element of a National Curriculum is that the qualifications are described through learning *outcomes* rather than factors of *effort.* The Regulations focus on what the candidate learns after completing the study programme, and not what he/she had to do in order to complete the study programme.

Under skills and general competencies, the term “professional engineer” is used and defined in accordance with the Regulations and notes. This presupposes that the student is to develop skills and general competencies based on knowledge of technical, scientific, and social science disciplines.

Regulation Learning Outcome Descriptors, Section 2

Knowledge

LU-K-1:	The candidate has broad knowledge that provides an integrated systems perspective on engineering in general, with specialization in his/her own engineering discipine.
LU-K-2:	The candidate has basic knowledge in mathematics, natural sciences, and relevant social and economic subjects and about how these may be integrated into the solution of engineering problems.
LU-K-3:	The candidate has knowledge of the history of technology, the development of technology, the engineer's role in society, and the consequences of the development and use of technology.
LU-K-4:	The candidate is familiar with research and development work in his/her own discipline, as well as relevant methods and ways of working in engineering.
LU-K-5:	The candidate is able to update his/her knowledge of the field, both by gathering information and through contact with professional communities and practical work.

Skills

LU-F-1:	The candidate can apply knowledge and relevant results of research and developmental work to solve theoretical, technical, and practical problems in engineering and be able to give reasons for his/her choices.
LU-F-2:	The candidate is has digital skills in in engineering subjects, is able to work in relevant laboratories, and masters methods and tools as a basis for goal-oriented and innovative work.
LU-F-3:	The candidate is able to identify, plan, and carry out engineering projects, tasks, trials, and experiments both independently and in teams.
LU-F-4:	The candidate is able to find, evaluate, use, and refer to information and professional subject matter and present this in a manner that focuseson a problem.
LU-F-5:	The candidate can contribute to new approaches, innovation, and entrepreneurship by developing and realizing sustainable and socially useful products, systems, and/or solutions.

General Competencies

LU-G-1:	The candidate has insight into environmental, health-related, social, and financial consequences of products and solutions in his/her field, and is able to put these into an ethical perspective and a life cycle perspective.
LU-G-2:	The candidate is able to communicate knowledge of engineering to different target groups, both in writing and orally in Norwegian and English, and is able to contribute to making the significance and consequences of technology visible.
LU-G-3:	The candidate is able to reflect on his/her own academic performance independently, in teams, and in interdisciplinary contexts, and is able to adjust this to the relevant work situation.

LU-G-4: The candidate is able to contribute to the development of good practice by taking part in academic discussions in the subject area and share his/her knowledge and experience with others.

Implementing the National Curriculum

The qualifications framework demands a new way of thinking. The focus is on the students' learning and learning outcomes. To ensure a successful implementation of the National Curriculum, the process from qualification descriptors at an educational level to qualification-based descriptors at a course level in each programme option is essential. Qualification-based education is to ensure uniformity between institutions and allow for mobility. This leads to obvious changes in planning documents and in practical teaching. In a letter to UHR dated 8 March, the Ministry of Education and Research writes: "Implementation of the revised National Curriculum demands comprehensive revision at each institution."

Based on the qualification descriptors at an educational level, learning outcome/qualification descriptors must be developed within the various study programmes. The target is the individual student and this must be reflected in qualification descriptor content, form, and specification. To ensure high quality educational programmes, each institution will have to collaborate with each other, professional representatives, and the students. Business and industry have signalled that equivalent study programmes and programme options should be as interchangeable as possible in terms of their learning outcomes across institutions. The titles of study programmes and programme options are to reflect their content. An extensive and critical review and a systematic structuring of study programmes and programme options is necessary in order to make industry aware of what types of education are offered and in what way they will be offered. The academic leadership must be a driving force during implementation and through their involvement demonstrate what contribution this work will have on the institution's academic work.

In order to develop course plans that are based on the study programme and programme options' qualification descriptors, tools that visualize how a course contributes to the overall learning outcomes can be useful (Appendix 7). When combined, the visualization must demonstrate that the learning outcomes for the study programme and the programme options are met.

The institutions must be able to document how the national qualifications are met at a study programme, programme option, and course levels. To ensure that qualifications are all documented in study programme, programme option, and course plans, it is necessary to approach the components and the totality analogously. While different programmes/options will have different visualizations because the academic profile will affect which qualifications carry the most weight, students are to obtain the same learning outcomes. Each institution is thus free to choose content, organization, and forms of assessment in order to meet this goal.

<u>Criteria for Success[2] for Implementation:</u>

- The implementation must be based on the academic management
- Institutional guidelines for developing the programme plan

[2] The list is based on experience presented by Senior Adviser Etelka Tamminen Dahl, University of Bergen: The implementation of qualification-based education, National Curriculum Regulations Committee's consultation conference regarding national Guidelines on 28 September, 2010 in Oslo.

- Realistic learning outcome descriptors
- Attention to international issues
- Learning methods and forms of assessment must be chosen based on their correspondence with the learning outcome descriptors

Demands for learning outcomes as stated in the Regulations, is at an educational level. That includes a variety of different programmes of study. Within this given framework, universities and university colleges will determine their specific study programmes and programme options in Engineering, but they must ensure that those who complete and graduate in a bachelor's programme in engineering have met the learning outcomes specified in the Regulations, notes, and Guidelines.

Learning outcome descriptors at a study programme and programme options level, and courses that corresponds with the Guidelines, have been developed in a national process under the direction of the National Council for Technological Education These learning outcome descriptors are to contribute to academic collaboration between institutions as well as national and international mobility.

The programme plans for each study programme are to give a detailed demonstration of how the learning outcomes for a bachelor's degree in Engineering may be achieved. The programme plan and course plans are to specify this in terms of knowledge, skills, and general competencies, as well as forms of assessment and methods of work and learning.

The study programme is to ensure that the students meet all the learning outcome requirements. This in turn requires that the institutions develop study programmes and students' individual study plans in a comprehensive manner. The various courses and course groups are to not be developed separately, rather collectively. This means that each institution must arrange for an interdisciplinary process where all parts are included in designing the study programme. In such a process, scientific staff (employed in technical, scientific, or social science industries), laboratory personnel, students, and administrative workers are to be involved.

3 Structure and Content (Section 3 in the Regulations)

In order to make the transition into the qualifications framework easier, the Regulations use standardized national terminology. A programme is made up of courses and course groups. A bachelor's degree in Engineering has four course groups. While some courses are mandatory, some are elective courses that students can choose for their education profile.

A study programme is a cohesive education made up of courses and course groups. A study programme may have several programme options. Combined, the study programme, the programme's course groups, and each course is to meet the learning outcome requirements specified in Section2. The programme's title and plan are to correspond to its content (cf.: Section 4-2 1 in NOKUT's QA Regulations, 2011).

Information and communication technology is to be integrated and used as an educational tool both academically and pedagogically. The institutions are to remain in close contact with relevant industries both during the development and the execution of the study programmes.

A bachelor's degree in Engineering is achieved after completing the programme. The candidate must have passed a minimum of 180 credits comprised of the following course groups:

- 30 credits common courses
- 50 credits programme courses
- 70 credits technical specialization courses
- 30 credits elective courses

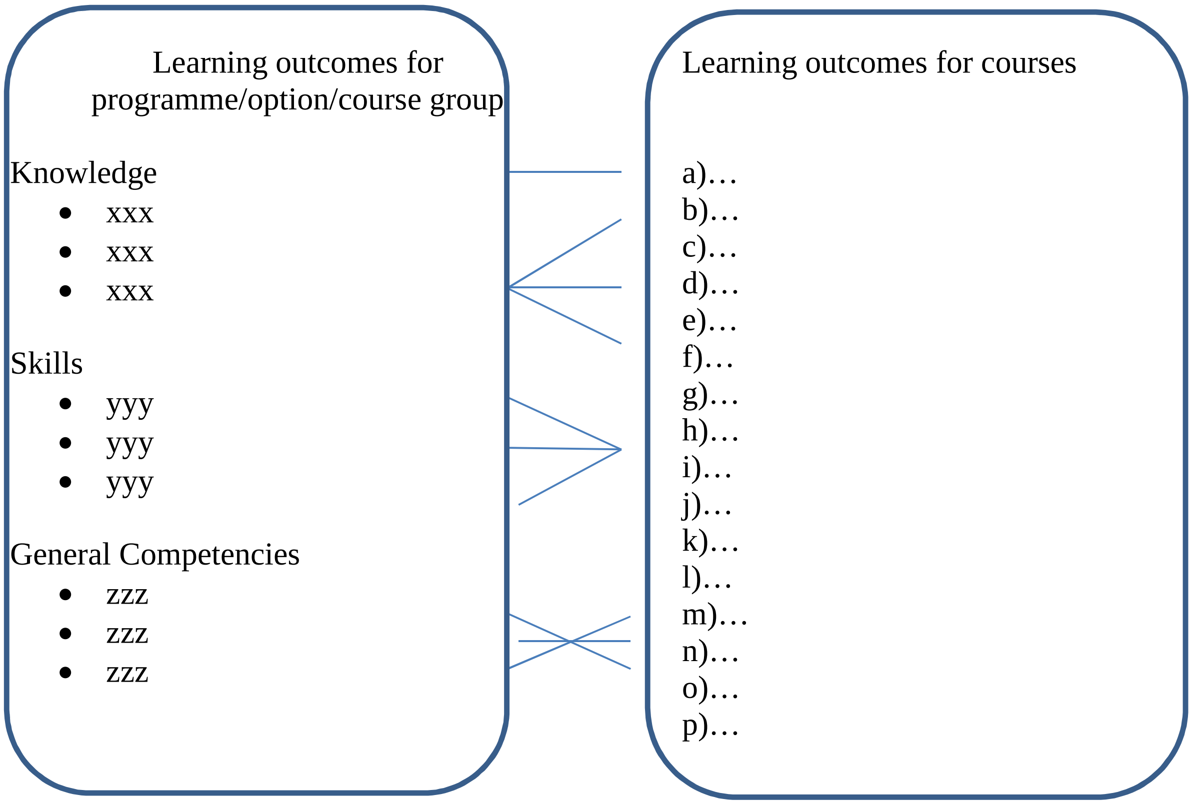
The institutions can combine elements within a course group, and from different course groups to larger courses. However, the combined extent of each course group is to not deviate from the approved framework.

The four course groups relate to engineering, the study programme, the programme options, and to the manner in which these make a foundation for the engineering field, discipline, and subject area:

- Common courses are mainly related to engineering and create a basis for the engineering field.
- Programme courses are mainly related to the study programme and create a basis for the discipline.
- Technical specialization courses are mainly related to the programme options and create a basis for the subject area. The undergraduate thesis would be included under this.
- Optional courses are meant to provide a foundation for the students' preferred educational profile, and may allow for both national and international mobility.

The figure below illustrates possible correlations between courses and learning outcomes. Examples of tools that illustrate how learning outcomes are met are listed in Appendix 7.

Figure 1 Correlation between learning outcome descriptors and courses



The above figure illustrates the various ways academic learning outcomes at the study programme, programme option, and course levels may be implemented in or with single subjects:

1:1 A set of learning outcomes may be implemented in a single subject

1:N A set of learning outcomes may be implemented in combination with several various subjects

M:1 Multiple sets of learning outcomes may be implemented in a single subject

M:N Multiple sets of learning outcomes may be implemented in combination with several various subjects

The way learning outcomes are implemented at the study programme, programme option, and course levels may vary depending on the set.

4 Characteristics of the Revised Engineering Education

The characteristics and related indicators used to describe quality in Engineering are to contribute to a continuous increase in quality. An education of high international quality will match the characteristics and indicators satisfactorily.

The institutions must work towards meeting these characteristics. The institutions will use these to follow up on and consider changes and reviews of study programme quality. The characteristics give the institutions the possibility for cross-institutional comparison. A high quality Engineering Education is to have the following characteristics:

I. Integrated and holistic education
II. In front by means of professional updating
III. Updated learning- and evaluation methods
IV. Research and development orientation
V. Professional competencies and practical skills
VI. International competencies
VII. Interdisciplinary focus, innovation, and entrepreneurship
VIII. Student effort and coping
IX. Engineering formation

Integrated and holistic education

The study programmes have an integrated and holistic profile. By 'integrated' it is meant that the different education components (courses, learning methods, pedagogical tools, syllabus, forms of assessment, etc.) are seen as a comprehensive unit. The study programme is developed and carried out with extensive inter- and cross-institutional cooperation. Engineering students will recognize the direct value of mathematics in combination with engineering. Professionals with backgrounds in technology, science, and social science collaborate and are capable of connecting these fields. Teachers of natural science and social science motivate students to recognize relevant and important connections to technology. Teachers of technology motivate students to recognize relevant and important connections to natural science and social science. Mathematics, physics, and chemistry represent a central basis in engineering, which will be well preserved through integration and visibility during the education.

Learning outcome descriptors are not lose elements; they control the choice of learning methods and forms of assessment. The internal guidelines of each institution ensure a comprehensive education.

Courses worth a minimum of 10 credits contribute to an integrated education with a particular focus on systems thinking and integration.

In front by means of professional updating

The academic staff in the education programmes always strive to update the study programmes. This involves the results of new research, didactical development, and relevant developments in business and industry. The findings are reviewed to see whether and how they should be included in the study programmes. The academic staff makes sure to stay theoretically, practically, and didactically updated. The institutions exchange new ideas for improvements to the study programmes and collaborate nationally on establishing strong academic environments. The institutions also actively offer the professional sectors new knowledge as part of additional education.

Updated learning- and evaluation methods

The study programmes offer a variety of learning methods and forms of assessment, and allow varied work requirements and methods. Instruction is arranged in such a way to avoid isolating students too much in the work, and to let them practice working independently and in various group settings. The students provide each other with guidance and written and oral feedback. Mandatory participation and work requirements are stated in each course plan and contribute to effective learning. The institution is to document that the students have achieved the specific learning outcomes and use a broad range of forms of assessment.

The academic group is to conduct systematic reflection of the didactics of engineering together with technological and pedagogical groups.

Research and development orientation

The academic staff contributes to academic research and development orientation through active and conscious collaboration with research (R&D) groups nationally and internationally. The undergraduate thesis supports either the institution’s own engineering research or similar research in an external institution where the thesis is performed.

Professional competencies and practical skills

Science, technology, and social science are all effectively integrated and help students solve problems in engineering in a comprehensive manner. The students are faced with both theory and practice, and are to approach these in context. Such an approach generates motivation and learning. Practice is incorporated in various ways.

The education is to be closely connected to relevant industries. Teaching focuses largely on laboratory and practical work, and approaches theory from a practical perspective. Close connections to industries opens up for relevant practical engineering internships with credits.

International competencies

Internationalization is an important part of academic quality and provides an education with international relevance in terms of further studies and job opportunities. The programmes are to arrange for increased mobility and institutional collaboration.

Internationalization at the academic institution is arranged in several ways, including international and multicultural perspectives, English syllabuses, and foreign guest speakers/lecturers.

The institution uses international collaboration agreements actively to develop international competencies, linguistic skills, and cultural understanding.

Various learning methods, such as the active use of English in the classroom, oral presentations and written assignments, and the active use of international resources, perspectives, and standards develop the students' international competencies.

The international semester is an integral part of the Engineering Education that promotes both international competencies and linguistic skills. This also applies to students who are not able to take advantage of travelling to institutions abroad.

Interdisciplinary focus, innovation, and entrepreneurship
The programme offers practice in collaboration, and aims to develop both systematic and creative thinking. The programme also provides skills to realize ideas through sustainable business development. Student projects across disciplines and in collaboration with other subjects are designed to promote interdisciplinary thinking.

Student effort and coping
The course plans are to clearly state how the students' efforts should be allocated in terms of the various learning methods.

Weighting of professional engineering and ways of working in the course group "common courses" promote academic achievement throughout the education. This course group motivates and makes students aware of their programme options, as well as allowing students to practice good study techniques. The students practice computing, writing, reading, and presentation techniques from day one in the education. The common courses demonstrate correlations within the education and helps establish an academic unit both within disciplines and across study programmes.

Engineering formation
The education includes ethical and environmental perspectives, as well as economic and international competencies. An important aspect is how the engineering disciplines stimulate technological and social development both in terms of the past and the future. Scientific thinking and methods are integrated parts of the education. The students develop analytical, methodical, and practical skills. Interdisciplinary collaboration and problem-solving represent important learning methods, as do oral and written communication. Creativity, innovation, and entrepreneurship are integrated educational elements. Engineering Formation is developed through sound scientific knowledge and its conscious application.

5 Indicators of Revised Engineering Education

Based on the characteristics described in Chapter 4 and the learning outcome descriptors for Engineering Education in Chapter 2, a set of indicators have been established. These indicators have three main functions: to simplify, document, and communicate. The indicators are based on the learning outcome descriptors and in the characteristics of the revised Engineering Education in such a way that they contribute to reaching the learning outcomes and characteristics.

The indicators are an internal quality-control tool for the institutions. They may be used as a useful checklist when designing programme plans. The institution may choose to focus on specific indicators in order to reach certain goals.

Indicators linked to the characteristics of Engineering Education are stated in the table below:

Table 1 Suggested indicators of the various characteristics

Characteristics	Relevant indicators
I. Integrated and holistic education	1. Internal and / or external technical cooperation on the design and implementation of programs of study, subject groups and subjects. 2. Good academic progress in the engineering academic courses that build on the qualifications in science and social topics. 3. Mathematics is a tool that academic staff and students use consciously and actively in the other subjects.
II. In front by means of professional updating	4. Benchmarking of study programmes both nationally and internationally. 5. Systematic updating of study programs based on new knowledge and experience. 6. In the forefront of relevant research, engineering didactics and professional competence.
III. Updated learning- and evaluation methods	7. Teaching methods are based on updated engineering didactics qualifications. 8. Cooperation on learning methods with other disciplines, including pedagogy. 9. Variation in learning and evaluation methods. 10. Teaching methods to activate critical, reflective and conscious thinking.
IV. Research and development orientation	11. Educational programmes conducted in conscious and active contact with internal, national or international R & D environments. 12. Continuous search for new knowledge in dialogue with experts, students, society and industry.
V. Professional competencies and practical skills	13. The programme is carried out in close contact with society and industry. 14. Systematic development of theoretical and practical engineering skills through academic studies. 15. Training on relevant and modern equipment and

		development of knowledge that contribute to a holistic and systems perspective by problem-identification, problem-solving and innovation. Bachelor's theses are rooted in actual engineering issues
VI.	International competencies	16. Active use of English language in teaching, oral presentations and written material. 17. Active use of international resources, perspectives and standards in the learning process. 18. Active use of international agreements in relation to research, staff, students and study programmes.
VII.	Interdisciplinary focus, innovation, and entrepreneurship	19. Teaching methods and evaluation methods to stimulate collaboration across engineering disciplines and interdisciplinary approaches in a broader perspective. 20. Teaching that stimulates enthusiasm and creativity that motivate development and innovation. 21. Teaching and evaluation methods to stimulate the ability to develop and realize business opportunities of technology.
VIII.	Student effort and coping	22. Study environment, teaching and evaluation methods to stimulate increased student effort and academic achievement. 23. The first semester gives motivation for the engineering profession, the study and support a creative learning environment both within own engineering profession and across programmes.
IX.	Engineering formation	24. The programme and its implementation contribute to social responsibility, environmental awareness, ethical responsibility and understanding of the consequences of technology. 25. The program and its implementation develop high professional qualifications, understanding of the systems view and respect for other disciplines.

6 Learning Outcome Descriptors or Supplementary Text for Disciplines, Courses, and Topics

The Regulations state that all study programmes and programme options, as well as all courses, are to include learning outcome descriptors.

These national Guidelines define learning outcome descriptors for the following engineering disciplines: Civil Engineering, Computer Engineering, Electrical Engineering, Chemical Engineering, and Mechanical Engineering. The learning outcome descriptors govern study programmes under these disciplines.

The Guidelines include governing learning outcome descriptors and supplementary text for mathematics, science, and social science.

The new academic topics “Introduction to Professional Engineering and Engineering Ways of Working” and “Systems Engineering” are described in supplementary texts as support for institutions in the process of designing learning outcome descriptors. Examples of learning outcome descriptors are provided in Appendices 4 and 5.

The Guidelines include instructions regarding supervised professional training with credits, elective courses, internationalization, and the undergraduate thesis.

The learning outcome descriptors for the disciplines Civil Engineering, Computer Engineering, Electrical Engineering, Chemical Engineering, and Mechanical Engineering are described on the following pages with a starting point in the National Curriculum Regulations for higher education (NKR) and in Section2 in the Regulations regarding National Curriculum for Engineering Education. Implementation and further work by SAK (Chapter 10) will generate experience, and reviews will determine if they are in agreement with the descriptions given in Chapter 2 and if they support SAK’s work.

6.1 Learning Outcome Descriptors for Disciplines

Learning Outcome Descriptors for Civil Engineering

A candidate who has completed a 3-year bachelor's degree in Civil Engineering is to have mastered the following learning outcomes defined by knowledge, skills, and general competencies.

Knowledge

LU-B-K-1: The candidate has broad knowledge that provides an integrated systems perspective of engineering in general, and specialization in Civil Engineering.

LU-B-K-2: The candidate has basic knowledge in mathematics, natural science, relevant social and economic subjects, and of how these can be integrated in the resolution of problems in engineering.

LU-B-K-3: With a specialization in Civil Engineering, the candidate has knowledge of the history and development of technology, the engineer's role in society, as well as consequences of technological use and development.

LU-B-K-4: The candidate is familiar with research and developmental work within Civil Engineering, as well as relevant methods and ways of working in engineering.

LU-B-K-5: The candidate can update his/her knowledge of the field, both by gathering information and through interaction with professional communities and the practical field.

Skills

LU-B-F-1: The candidate can apply knowledge and relevant results of research and developmental work to solve theoretical, technical, and practical problems in Civil Engineering and be able to give reasons for his/her choices.

LU-B-F-2: The candidate has digital skills in engineering subjects, is able to work in relevant laboratories/fields, and masters methods and tools as a basis for goal-oriented and innovative work.

LU-B-F-3: The candidate is able to identify, plan, and carry out engineering projects, tasks, trials, and experiments both independently and in teams.

LU-B-F-4: The candidate is able to find, evaluate, use, and refer to information and professional subject matter, and present this in a manner that focuses on a problem.

LU-B-F-5: The candidate can contribute to new approaches, innovation, and entrepreneurship by developing and realizing sustainable and socially useful products, systems, and/or solutions.

General Competencies

LU-B-G-1: The candidate has insight into environmental, health-related, social, and financial consequences of products and solutions in Civil Engineering, and is able to put these into an ethical perspective and a life cycle perspective.

LU-B-G-2: The candidate is able to communicate knowledge of engineering to different target groups, both in writing and orally in Norwegian and in English, and is able to contribute to making the significance and consequences of technology visible.

LU-B-G-3: The candidate is able to reflect on his/her own academic performance independently, in teams, and in interdisciplinary contexts, and is able to adjust to the relevant work situation.

LU-B-G-4: The candidate is able to contribute to the development of good practice by taking part in academic discussions in the subject area and share his/her knowledge and experience with others.

Learning Outcome Descriptors for Computer Engineering
A candidate who has completed a 3-year bachelor's degree in Computer Engineering is to have accumulated the following learning outcomes defined by knowledge, skills, and general competencies.

Knowledge
LU-D-K-1: The candidate has broad knowledge that provides an integrated systems perspective of engineering in general, with specialization in Computer Engineering. Key knowledge points in Computer Engineering include problem-solving, software development, interface, as well as principles of computer system configuration and computer networks.
LU-D-K-2: The candidate has basic knowledge in mathematics, natural science, relevant social and economic subjects, and of how these can be integrated in the resolution of problems in information technology.
LU-D-K-3: With a specialization in Computer Engineering, the candidate has knowledge of the history and development of technology, the engineer's role in society, relevant laws associated with computer technology and software, as well as various consequences of the use of information-technology.
LU-D-K-4: The candidate is familiar with research and developmental work within Computer Engineering, as well as relevant methods and ways of working in engineering.
LU-D-K-5: The candidate can update his/her knowledge of the field, both by gathering information and through interaction with professional communities, user groups, and the practical field.

Skills
LU-D-F-1: The candidate can apply knowledge and relevant results of research and developmental work to solve theoretical, technical, and practical problems in Computer Engineering and be able to give reasons for his/her choices.
LU-D-F-2: The candidate masters methods and tools as a basis for goal-oriented and innovative work. This includes the following skills:

- Use operating systems, system software, and networks
- Configure demands and model, develop, integrate, and evaluate computer systems
- Use programming tools and systems development environments

LU-D-F-3: The candidate is able to identify, plan, and carry out projects, tasks, trials, and experiments in information-technology both independently and in teams.
LU-D-F-4: The candidate is able to find, evaluate, use, and refer to information and professional subject matter and present this in a manner that focuses on a problem.
LU-D-F-5: The candidate can contribute to new approaches, innovation, and entrepreneurship by developing and realizing sustainable and socially useful products, systems, and/or solutions where information technology is included.

General Competencies
LU-D-G-1: The candidate has insight into environmental, health-related, social, and financial consequences of products and solutions in Computer Engineering, and is able to put these into an ethical perspective and a life cycle perspective.

LU-D-G-2: The candidate is able to communicate knowledge of information-technology to different target groups, both in writing and orally in Norwegian and in English, and is able to contribute to making the significance and consequences of technology visible.
LU-D-G-3: The candidate is able to reflect on his/her own academic performance independently, in teams, and in interdisciplinary contexts, and is able to adjust this to the relevant work situation.
LU-D-G-4: The candidate is able to contribute to the development of good practice by taking part in academic discussions in the subject area and share his/her knowledge and experience with others.

Learning Outcome Descriptors for Electrical Engineering

A candidate who has completed a 3-year bachelor's degree in Electrical Engineering is to have accumulated the following learning outcomes defined by knowledge, skills, and general competencies.

Knowledge

LU-E-K-1: The candidate has broad knowledge that provides an integrated systems perspective of engineering in general, with specialization in Electrical Engineering. The candidate has extensive knowledge of electrical and magnetic field, electrical components, circuits, and systems.

LU-E-K-2: The candidate has basic knowledge in mathematics, natural science, relevant social and economic subjects, and of how these can be integrated in the resolution of problems in Electrical Engineering.

LU-E-K-3: With a specialization in Electrical Engineering, the candidate has knowledge of the history and development of technology, the engineer's role in society, as well as consequences of technological use and development.

LU-E-K-4: The candidate is familiar with research and development work, as well as relevant methods and ways of working within Electrical Engineering.

LU-E-K-5: The candidate can update his/her knowledge of the field, both by gathering information and interacting with professional communities and the practical field.

Skills

LU-E-F-1: The candidate can apply knowledge and relevant results of research and development work to solve theoretical, technical, and practical problems in Electrical Engineering and be able to give reasons for his/her choices.

LU-E-F-2: The candidate has digital skills in engineering subjects, is able to work in relevant laboratories/fields, and masters measurement techniques, troubleshooting, use of relevant instruments and software as a basis for goal-oriented and innovative work.

LU-E-F-3: The candidate is able to identify, plan, and carry out engineering projects, tasks, trials, and experiments both independently and in teams.

LU-E-F-4: The candidate is able to find, evaluate, use, and refer to information and professional subject matter, and present this in a manner that focuses on a problem.

LU-E-F-5: The candidate can contribute to new approaches, innovation, and entrepreneurship by developing and realizing sustainable and socially useful products, systems, and/or solutions.

General Competencies

LU-E-G-1: The candidate has insight into environmental, health-related, social, and financial consequences of products and solutions in Electrical Engineering, and is able to put these into an ethical perspective and a life cycle perspective.

LU-E-G-2: The candidate is able to communicate knowledge of engineering to different target groups, both in writing and orally in Norwegian and in English, and is able to contribute to making the significance and consequences of electrical technology visible.

LU-E-G-3: The candidate is able to reflect on his/her own academic performance independently, in teams, and in interdisciplinary contexts, and is able to adjust this to the relevant work situation.

LU-E-G-4: The candidate is able to contribute to the development of good practice by taking part in academic discussions in the subject area and share his/her knowledge and experience with others.

Learning Outcome Descriptors for Chemical Engineering
A candidate who has completed a 3-year bachelor's degree in Chemical Engineering is to have accumulated the following learning outcomes defined by knowledge, skills, and general competencies.

Knowledge
LU-K-K-1: The candidate has broad knowledge in various chemistry subjects (general chemistry, organic chemistry, physical chemistry, analytical chemistry, and laboratory techniques) that provides an integrated systems perspective of Chemical Engineering.
LU-K-K-2: The candidate has basic knowledge in mathematics, natural science, relevant social and economic subjects, and of how these can be integrated in the resolution of problems in engineering.
LU-K-K-3: With a basis in Chemical Engineering, the candidate has knowledge of the development of technology, the engineer's role in society, as well as consequences of technological use and development.
LU-K-K-4: The candidate is familiar with research and developmental work, as well as relevant methods and ways of working within Chemical Engineering.
LU-K-K-5: The candidate can update his/her knowledge of the field, both by gathering information and through interaction with professional communities and the practical field.

Skills
LU-K-F-1: The candidate can apply and process knowledge to solve problems in Chemical Engineering, suggest technical solution alternatives, analyse and assure quality of results.
LU-K-F-2: The candidate has digital skills and masters software and simulation programmes relevant to Chemical Engineering.
LU-K-F-3: The candidate is able to work in chemical laboratories, and masters methods in spectroscopy, chromatography, and electrochemistry that contribute to both analytical and innovative work. The candidate is also able to document analysis results in laboratory journals and write reports based on standardized formats.
LU-K-F-4: The candidate is able to find, evaluate, use, and refer to information and professional subject matter, and present this in a manner that focuses on a problem.
LU-K-F-5: The candidate can contribute to new approaches, innovation, and entrepreneurship by developing and realizing sustainable and socially useful products, systems, and/or solutions.

General Competencies
LU-K-G-1: The candidate has insight into environmental, health-related, social, and financial consequences of chemical products, analyses, and processes, and is able to put these into an ethical perspective and a life cycle perspective.
LU-K-G-2: The candidate is able to communicate knowledge of engineering to different target groups, both in writing and orally in Norwegian and in English, and is able to contribute to making the significance and consequences of technology visible.
LU-K-G-3: The candidate can handle chemicals appropriately and use HES data.
LU-K-G-4: The candidate is able to take part in academic discussions, is respectful and open towards other disciplines, and contributes to interdisciplinary work.

Learning Outcome Descriptors for Mechanical Engineering
A candidate who has completed a 3-year bachelor's degree in Mechanical Engineering is to have accumulated the following learning outcomes defined by knowledge, skills, and general competencies.

Knowledge
LU-B-K-1: The candidate has broad knowledge in construction and/or production, materials, and comprehensive systems- and product development, and other topics that contribute to relevant specialization or scope.
LU-B-K-2: The candidate has basic knowledge in mathematics, natural science, relevant social and economic subjects, and of how these can be integrated in systems- and product development.
LU-B-K-3: With a specialization in Mechanical Engineering, the candidate has knowledge of the history and development of technology, the engineer's role in society, as well as consequences of technological use and development.
LU-B-K-4: The candidate is familiar with research and development work and relevant methodology within Mechanical Engineering.
LU-B-K-5: The candidate can update his/her knowledge of the field, both by gathering information and through interaction with professional communities and the practical field.

Skills
LU-B-F-1: The candidate can apply knowledge of mathematics, physics, chemistry, and technological subjects work to devise, specify, plan, and solve technical problems in a well-reasoned and systematic manner.
LU-B-F-2: The candidate masters development methodology, is able to use programmes to model/simulate, and can realize solutions and systems.
LU-B-F-3: The candidate is able to identify, plan, and carry out engineering projects, experiments, simulations, as well as analyse, interpret, and use data, both independently and in teams.
LU-B-F-4: The candidate is able to find, evaluate, and use technical subject matter in a critical manner, and present this in a manner that focuses on a problem both in writing and orally.
LU-B-F-5: The candidate can contribute to new approaches, innovation, quality assurance, and entrepreneurship by developing and realizing sustainable and socially useful products, systems, and/or solutions.

General Competencies
LU-B-G-1: The candidate has insight into environmental, health-related, social, and financial consequences of products and solutions in Mechanical Engineering, and is able to put these into an ethical perspective and a life cycle perspective.
LU-B-G-2: The candidate is able to communicate knowledge of engineering to different target groups, both in writing and orally in Norwegian and in English, and is able to contribute to making the significance and consequences of technology visible.
LU-B-G-3: The candidate is able to reflect on his/her own academic performance independently, in teams, and in interdisciplinary contexts, and is able to adjust this to the relevant work situation.

LU-B-G-4: The candidate is able to contribute to the development of good practice by taking part in academic discussions in the subject area and share his/her knowledge and experience with others.

6.2. Learning Outcome Descriptors and Supplementary Text Relating to Mathematics, Science, and Social Science

Mathematics

Mathematics is an essential subject in all types of Engineering Education. The subject is a key factor in identifying, formulating, and solving problems in engineering. Mathematics improves academic communication between technology fields, nationally and internationally. From a lifelong learning perspective, basic mathematical skills lay the foundation for innovation, new approaches, and the development of mathematics-based competence. A solid basis in mathematics is thus a pillar in both academic and professional engineering. Learning outcomes must therefore include logical arguments and basic theoretical and practical understanding of mathematical concepts and ideas, as well as knowledge of and skilled use of established techniques and methods.

Engineering mathematics is often uniform across nations. The Regulations state that mathematics is to have an internationally comparative level. (Work is being done in addressing the issue of a qualifications-based description of mathematical subjects in Europe. This is task of the Mathematics Working Group in the European Society for Engineering Education (SEFI).) It is important that each institution remains informed about international work in mathematics in engineering.

In order to achieve the learning outcomes, the revised National Curriculum requires varied ways of working and forms of assessment. Mathematics courses should highlight this. Below are lists of various ways of working and forms of assessment applicable to mathematics courses. It is imperative that the students practice their calculation skills and are able to make those evaluations necessary to solve a complex equation or a practical problem. Didactic literature in mathematics notes that explaining your reasoning is a way of working that promotes mathematical comprehension (Grønmo et al., 2010).

An engineer will often solve mathematical problems with computers; academic mathematics should therefore include a clear calculation perspective that highlights a basic understanding for the possibilities and limitations of analytical and calculation-solving techniques. If students are taught programming in other courses, it is ideal to practice this actively in mathematics subjects as well. The focus should not be on skills in specific software, but rather on basic knowledge of mathematical problem-solving using algorithms, even if the instruction often is based on such software. A creative use of calculations equals a good understanding of traditional mathematics and good skills in elementary algebra. Early incorporation of calculation perspectives will expedite the incorporation of realistic examples both in mathematics and in mathematics-related subjects.

An Engineering Education is to include a minimum of 20 credits in mathematics. Of these, a minimum of 10 credits are to be common courses for all study programmes. Even though the scale and scope of mathematical topics is too significant to cover in 20 credits, mathematical topics and thorough practice of mathematical skills should be covered as broadly as possible in all study programmes. Mathematics is to be actively repeated in technological courses and in relevant interdisciplinary contexts in order to achieve the total learning outcomes.

Transition to a graduate degree in technology will include different mathematical requirements. Each institution must ensure that students are conscious of these requirements, and those of master's degrees at other institutions.

Current mathematical topics may include: concepts of function, inverse functions, limits, continuity, derivation, integration, integration techniques, differential equations emphasizing modelling, linear algebra, matrixes, determinants, system of linear equations, eigenvalues and eigenvectors, complex numbers, functions of several variables, partial derivatives, Laplace transformations, numerical sequences, differential algebra, exponential functions, Fourier series, combinatorics, set theory, discrete mathematics, mathematical analysis, graphs and trees, supplemented with numerical calculation techniques where natural.

Learning Outcomes

Knowledge

a) The candidate has developed a basic academic understanding of mathematics on which other subjects can build.
b) The candidate has knowledge of basic mathematical applications in engineering.
c) The candidate has knowledge of problem-solving and modelling to solve problems in engineering.
d) The candidate has extensive knowledge of core subjects such as derivation, integration, and differential equations.
e) The candidate has extensive knowledge of core subject matrixes, and eigenvalues in linear algebra.
f) The candidate has good knowledge of numerical calculations and their possibilities and limitations.
g) The candidate has good knowledge in other mathematical subjects relevant to his/her discipline.

Skills

a) The candidate has a relevant mathematical symbol and formula apparatus.
b) The candidate is able to manipulate symbols and formulas.
c) The candidate is able to reason mathematically.
d) The candidate is able to articulate problems in engineering in a mathematical way.
e) The candidate is able to solve problems using both analytical and numerical methods.
f) The candidate has good calculation skills.
g) The candidate is able to use mathematical methods and tools relevant to his/her field.
h) The candidate is able to identify mathematical applications in engineering.
i) The candidate can evaluate results from mathematical limitations (analytical and numerical).
j) The candidate is able to comprehend and use mathematical representations.

General Competencies

a) The candidate is able to use mathematics to communicate problems in engineering.
b) The candidate comprehends that change and change per unit time can be measured, calculated, totalled, and included in equations.

c) The candidate comprehends that the level of precision in the mathematical language is what makes it eligible to structure problems in engineering and to find solutions.
d) The candidate has mathematical comprehension laying the foundation for lifelong learning.

Organization and Ways of Working
Lectures, calculations, colloquiums, take-home assignments with and without technological aids, written individual and group projects with oral presentations. Problem-based learning and use of technological aids.

Relevant Literature, Professional Subject Matter, and Sources
Textbooks such as “Calculus/Mathematical Analysis,” “Linear Algebra.”

Work Requirements
Mandatory calculations and/or mandatory submissions.

Assessment/Exams
Assessment of each course must be adapted to the learning process and different forms of assessment may be applicable: written final examination, oral examination, portfolio, individual oral test, practical test, written test. A portfolio may include several forms of assessment; written final examination, continuous assessment, mandatory individual or group reports, projects. If a final grade is based on more than one form of assessment, each assessment must be passed, and individual assessment will be included.

Natural Science
Good knowledge in natural science subjects is important for all engineers and lays the foundation for engineering subjects. Natural science is here defined as physics, chemistry, and statistics.

Natural science subjects are key factors in the comprehension and development of engineering disciplines, and to gain an insight in how your own work affects your surroundings. These subjects play an important role in the interaction and the challenges that develop between technology and society. The entirety and correlations between natural science and engineering must be affirmed, particularly the correlation between basic theory and practice. Natural science is viewed from a social perspective through its interactions with other courses in other course groups.

Knowledge in natural science lays the foundation for lifelong learning and promotes general education.

Learning Outcomes
Knowledge

a) The candidate is familiar with the ways natural science is applied comprehensively, i.e. how physical and chemical phenomena correlate, and how statistics and mathematics are necessary tools in order to measure, describe, and evaluate results.
b) The candidate is familiar with basic theories and concepts in science.
c) The candidate is familiar with the laws of physics and how they may be applied to model observable phenomena, and is able to comprehend a model's validity.
d) The candidate is familiar with basic principles, theories, and concepts in chemistry, and how these relate to his/her discipline.
e) The candidate is familiar with basic correlations between chemistry and practical usages.
f) The candidate is able to interpret descriptive statistics, is familiar with basic probability theory, specific probability distributions, and the theoretical foundations of estimation, confidence intervals, and statistical hypothesis testing.
g) The candidate is experienced in using relevant electronic aids.

Skills

a) The candidate has the necessary basis for reading professional subject matter relevant to his/her discipline.
b) The candidate is able to use principles and concepts in physics and chemistry within his/her discipline.
c) The candidate has a relevant concept and formula apparatus.
d) The candidate is able to explain basic phenomena in physics and chemistry, and to use these in order to explain problems in engineering.
e) The candidate has basic skills in laboratory work, writing reports, and presenting results.
f) The candidate is able to collect, analyse, and present numerical data.
g) The candidate masters basic probability calculation and is able to estimate, conduct statistical hypothesis testing and simple correlation/regression analyses.

General Competencies

a) The candidate comprehends the world around him/her and the role of natural science in the interaction between technological developments and society. The candidate also has some insight into the environmental and ethical challenges today and in the future.
b) The candidate is able to achieve relevant solutions to problems in engineering through the use of physical, chemical, and statistical studies and methods.
c) The candidate comprehends physical, chemical, and statistical methods and ways of thinking, and is able to communicate these orally and in writing.
d) The candidate is able to contribute to the development of Engineering Education and general education.

Learning Outcome Descriptor Instructions
People today are surrounded by technology and new technological products throughout their lives. Physics is a fundamental pillar in many of these products, and thus comprehension of the laws of physics is highlighted in Engineering Educations. In Upper Secondary School, both traditional and modern physics are included in the course ‘Physics I,’ on which physics courses in Engineering Educations should be based. Physics courses in all study programmes must consolidate and deepen the students’ knowledge in traditional (basic mechanics such as speed, acceleration, forces, and Newton’s laws of vectors; energy, effect, and laws of conservation) and modern physics. Basic thermodynamic concepts and principles must also be covered. When it comes to theory and applications, each physics course is also to be adapted to the applicable discipline. Relevant topics include mechanics, thermodynamics, electromagnetics, fluid dynamics, quantum physics, and wave physics. It is important to make clear the correlation between the basic principles of physics and technical concepts in engineering.

Prerequisite knowledge beyond general Higher Education Admission Qualification is not required in chemistry; basic knowledge in chemistry is thus necessary. This includes knowledge of the periodic table, properties of the elements, molecular structure and bonding, calculations of quantity and the concept of equilibrium, solutions, acids and bases, reduction and oxidation reactions, corrosion, electrochemistry, gasses, thermodynamics and energy, reaction rate, and simple organic chemistry with a focus on industrially significant compounds such as plastic and petroleum compounds. Proper handling, use, storage, and disposal of chemicals, as well as basic HES is to be taught. Higher level courses are to be adapted to the different disciplines. Relevant topics may be materials technology, electrical conductors, mass and energy balances, crystal structure and phase diagrams, new energy sources, use and comprehension of materiel and materials of complex chemical structure, quality assurance and control, evaluation of products and processes, and environmental consequences. Good knowledge and skills in chemistry in relation to a specific discipline lays a strong foundation for a future career, is a basis for further development and new ideas, and contributes to an active attitude towards environmental challenges.

Relevant topics in statistics are the same for all disciplines, and are meant to extend statistic courses from Upper Secondary School. Descriptive statistics should include central tendency and dispersion and simple graphic illustrations. Topics typically covered in probability calculation include: introduction to the probability concept; conditional probability; random variable; probability distribution; expectation and variance; binomial, Poisson, hypergeometric, normal, and exponential distribution; and the central limit theorem. Statistical analysis should include estimation, confidence interval, and statistical hypothesis testing in normal and binomial distribution, effect size, and introduction to correlation and linear regression. The many uses of statistics in engineering should be highlighted through various examples. Statistics are also important in terms of general education and in everyday life. Social sciences and risk and reliability should also be discussed.

Statistics has practical properties and may be applied to data analyses from laboratory or field work, or programming of simulation models with random elements, and mathematics may provide a correlation between measurable values and physical models. Possible combinations of statistics topics may be measurement techniques or experimental work.

The interaction between experiments and theoretical models is typical for natural science subjects. It is thus important that the students conduct experiments and comprehend the application of models for physical/scientific systems and phenomena. Problem-solving and communication of results and studies is an essential part of Engineering Education.

Practical applications should be included as an integrated part of the education. Students are thus ensured familiarity with experimental methods and the use of experimental equipment. Laboratory work during the three years of study should be chosen in a manner that ensures progression from simple registration of data to more complex correlations to independent experimental research in relation to the undergraduate thesis.

Natural science subjects are to make up a minimum of 15 credits. Each institution must ensure that the scientific scope is sufficient for transition into further education. The distribution of physics, chemistry, and statistics is up to each institution. The Regulations do not require an equal distribution between the subjects, but the institutions are responsible for meeting the learning outcomes described in Section 2 and in this chapter.

Social Science

The engineering profession is often interdisciplinary. It is thus important that the education prepares the engineer for collaborating with others and in relation to society and industry. He/she must be familiar with the professional rules, organization, value creation, productivity, and profitability. He/she must also be able to work with others within his/her discipline and in relation to other professions and people with other cultural backgrounds. The engineer must therefore be comfortable in his/her position, as well as have humility and respect for others' contributions. Candidates should practice teamwork during their studies, as this is a typical way of working in engineering. Communication is a key concept and in today's global society, it is particularly important that engineers are able to communicate effectively orally and in writing, in Norwegian and in English.

Innovation and entrepreneurship are important elements in relation to the business market of the future; engineers have a particularly important role as innovators and developers of products and establishments. The engineer must also possess basic knowledge in economics and accounting in order to properly conduct calculations of cost and profitability.

The Regulations emphasize in Section1 that technological, scientific, and social science topics are to be integrated and considered comprehensively. The education is to preserve the interaction between ethics, environment, technology, individuals, and society. Such interaction requires changes in existing courses and programmes. The Regulations state that progression-based social science competencies should be built up during all three years of study. This requires an incorporation of social science competencies in common courses, programme courses, technical specialization courses, elective courses, and the undergraduate thesis.

Several social science subjects must be viewed in correlation with topics from "Professional Engineering and Ways of Working," "Engineering Systems Thinking," and "The Undergraduate Thesis." Project management should be included early in the study programme and in the undergraduate thesis.

The learning outcome descriptors include a minimum requirement that must be met by all study programmes. Each programme is encouraged to offer social science topics that cover areas the programme specializes in, or areas the programme wishes to focus on. Social science topics should also be included in the elective course list.

Learning Outcomes

Knowledge

a) The candidate has knowledge of the roles of technology and engineers in social development.
b) The candidate has knowledge of professional rules and interactions.
c) The candidate has basic knowledge of professional organization, value creation, productivity, and profitability.

d) The candidate has basic knowledge of economics.
e) The candidate has knowledge of innovative processes and entrepreneurship.
f) The candidate has knowledge about establishing and executing projects.

Skills

a) The candidate is able to assess profitability and economic risk.
b) The candidate is able to contribute to new approaches, innovation, and entrepreneurship through his/her participation in development and realization of sustainable and socially useful products, systems, and solutions.
c) The candidate is able to communicate orally and in writing about his/her discipline both in Norwegian and in English, and can contribute in interdisciplinary collaborations and in public debates.

General Competencies

a) The candidate is able to initiate smaller projects, and through proper management, conserve human, professional, economic, ethical, and social considerations.
b) The candidate is able to recognize an interdisciplinary correlation between economics, management, ethics, society, technology, and the environment.
c) The candidate comprehends the meaning of cultural competencies.

A specification and stronger emphasis of key learning elements included in each learning outcome descriptor, is included in Appendix 3.

6.3 Supplementary Texts for Specific Topics and Courses

Introduction to Professional Engineering and Ways of Working

By learning about ways of working in engineering and thus gaining an understanding of technological consequences, the students will become familiar with engineering on a professional level. Exposing students to the whole range of engineering promotes a comprehensive, open, and curious approach to learning, and will motivate the students.

The students are to be introduced to ways of working in engineering, in terms of new approaches, defining problems, analysis, specification, choosing method, generating solutions, evaluation, and reporting. The students are to get an insight to the analytical, structured, goal-oriented, and innovative work engineers do, and they must learn the importance of being conscious of the consequences technological solutions generate from a social, environmental, and ethical perspective. The students are also to practice written and oral communication both in Norwegian and in English. This will lay an important foundation for further independent learning. The instruction is to require high student activity and create a basis for student work ethic.

The students are to get to know their peers in their study programmes and in other study programmes, and thereby develop a sense of belonging, assurance, and security during their education. Good study techniques and habits are to be promoted.

Relevant topics that may contribute to meeting the learning outcomes include: project work, writing reports, presentation techniques, history of technology, ethics, health, environment and safety, life cycle analyses, project economics, laboratory work, computational perspectives using computers, and use of algorithms and mathematical calculations using computers. The students are to meet with relevant industries, and assignments are to be based on real problems that challenge perspectives in engineering.

This type of instruction provides increased motivation and thus also increased student flow. The institutions are encouraged to use a broad and varied selection of ways of working and learning methods. For instance: welcome weekend, entrepreneur camp focusing on eco-efficient solutions, excursions, poster presentations, laboratory assignments, intensive theme weeks, active use of guest lecturers, Venture Cup, and colloquia.

The students may be actively involved by presenting professional subject matter and completing assignments such as laboratory exercises and industrial visits. Students may present individually or in groups, to each other, or in plenary. Every student submits material and prepares to present, but only a selection are chosen to present. The students may also be encouraged to give each other feedback in the learning process. It is advantageous to involve second- or third-year students in courses that include learning outcomes requiring active participation in presentations, completion, guidance, and feedback.

One example of learning outcome descriptor for "Introduction to Professional Engineering and Ways of Working" is included in Appendix 4.

Engineering Systems Thinking

Collaborating systems play an important part in today's society. Interdisciplinary work based in a specific field is thus a key factor in engineering activity. Modelling and comprehensive systems thinking are significant and fundamental in engineering. These create a basis for interdisciplinary application of acquired qualifications in technology, natural science, and social science to solve complex technological tasks. A solid basis in modelling techniques is thus a key factor in an Engineering Education and for professional engineering. Simplification through models is important in order to analyse systems and for the engineer to generate new technical solutions.

"Engineering Systems Thinking" is one of the new academic elements in the National Curriculum and is to promote comprehensive and interdisciplinary approaches to engineering. Engineering systems thinking prepares the students for professional engineering and stipulates that the students acquire engineering qualifications in their discipline so they are able to work from a systemic whole, from simple to more complex systems. Engineering systems thinking is also to provide students with a better basis for understanding life cycle thinking, environmental and social consequences of technology, and for developing Engineering Education. Engineering systems thinking is to lay the foundation for completing an undergraduate thesis based on real problems.

Relevant topics that may contribute to the learning outcomes include: simplified representation of complex systems, subsystems, quality systems, eco-systems, mass and energy balances, uses of strategic analysis and uncertainty, risk analysis, concepts, concept assessment, concept evaluation, control systems (technical, economic, and administrative), flowcharts, functionality, environmental health and safety (HES). The learning outcomes as described in the Regulations require integration of the education courses, and that they must be viewed cohesively and in context. A natural approach may be to include these topics in other relevant courses in each study programme in order to achieve the total learning outcomes.

Students should work with engineering systems thinking in teams. Teamwork can occur both within a study programme and across study programmes. The institutions are encouraged to use a broad and varied selection of ways of working and learning methods that contribute to achieving the learning outcomes. An example of this is the teaching method "Experts in Teamwork" at the Norwegian University of Science and Technology (NTNU) in Trondheim.

An example of learning outcome descriptors for engineering systems thinking is included in Appendix 5.

Internationalization
The National Curriculum requires institutions to ensure that their Engineering Education includes international perspectives and that their candidates are able to function internationally.

The institution is to arrange for an international semester as part of the education. A facilitated semester abroad in collaboration with foreign institutions provides the students with international competencies both by Norwegian students studying abroad, and by foreign students studying in the Norwegian institution alongside Norwegian students. Students that are unable to study abroad can develop international competencies in Norway.

Facilitation of internationalization and the development of international competencies may be managed in several ways:

- International and multicultural perspectives included in the study programme
- English syllabi and foreign guest lecturers
- Various learning methods and forms of assessment

The international competencies must be specified in the programme plans.
Interest and insight in the importance of international orientation is essential in order for foreign languages and international perspectives to become integrated parts of the programme. The institutions should use their international collaboration agreements to develop international competencies, linguistic skills, and cultural understanding.

An international semester can be linked to the elective courses, which makes up one semester. Linguistic skills in English must be emphasized to achieve the learning outcomes.

Elective Courses
Elective courses are defined differently than the elective courses mentioned in previous National Curricula.

- Elective courses are meant to promote professional specialization in terms of scope.
- Elective courses lay a foundation for the students' desired professional profile and arranges for national and international mobility.

In order to contribute to professional specialization, elective courses should be included later in the education, but not conflict with the undergraduate thesis. The level of approved elective courses should reflect this.

Institutions are free to choose what elective courses they will offer, and have in that respect, a significant influence over what courses the students choose. The institution may develop courses worth 10 credits or more. Courses may consist of various subjects, which allows the institution to offer a semester course (30 credits).

Students should be able to acquire those qualifications required for acceptance into relevant master's programmes in technology. Students that wish to develop a specific subject profile that may support work in sectors typically not associated with engineering (culture, health, assistance, etc.), should be able to use elective courses for this purpose.

Courses taught in English may also be added to this course group in order to promote the institution internationally.

The institutions are to take advantage of the fact that elective courses make approval of transfer credits from other higher education institutions nationally or internationally easier. The qualifications a student brings with him/her from elective courses completed at that or another institution should ideally be reflected in the undergraduate thesis.

The institutions must keep up with the increased demand for supervision required by the National Curriculum. The students must be given the option of having a supervisor or an advisor as early as possible.

Practical training with credits
Practical training that awards credits is by no means mandatory, but is rather a practice each institution chooses whether they wish to offer or not. Practical training with credits may be included under elective courses, or with a maximum of 10 credits under technical specialization courses.

Practical training with credits must be relevant to the student's technical specialization. The course is to provide the student with professional engineering tasks and practice, and must be offered at a later point during the education. Students are required to integrate theory and practical training in real engineering projects. The students must also submit written reports, and may also make an oral presentation. These elements are included in the evaluation of the practical training.
Form of assessment is specified in the syllabus.

A practical training institution may be a company, an agency, an organization, or another place where engineers work. Practical training with credits in an approved institution is equal to other academic training programmes.

- Course plans for practical training with credits must be available; knowledge, skills, and general competencies as a result of the practical training is to be included.
- The academic institution is responsible for content, quality, and assessment of practical training.
- The academic institution is to collaborate with the practical training institution on ensuring that the practical training is relevant to the education.
- The practical training is to be organized through official agreements between the academic institution and the practical training institution; the collaboration must be made official as a three-part collaboration, involving the academic institution, the practical training institution, and the student.
- The practical training institution is to provide a good framework for the practical training.
- The practical training institution is to ensure that the student is made familiar with and follows those HES rules and other standards that apply at the institution.
- The practical training supervisor must have/acquire the necessary qualifications that apply during the practical training period.
- The practical training is assessed based on the grade scale specified in the course plan.

If an institution offers practical training with credits, the institution's regulations for quality assurance of mandatory practical training in other types of bachelor's education also apply to practical training in the Engineering Educations.

Bachelor's Thesis

The bachelor's thesis (20 credits) is the final course in Engineering Education. The thesis is to be anchored in real engineering problems from the social or business sectors or research and development work. Through the thesis, the students are expected to demonstrate thorough comprehension of engineering. They are to integrate previously learned knowledge and demonstrate an ability to acquire new knowledge to solve a problem. The thesis is to be viewed cohesively and illustrate the candidate's insight into environmental, health-related, social, and economic consequences of products and solutions in engineering, and ability to view these in both an ethical perspective and a life cycle perspective.

The undergraduate thesis is to provide students with practise in applying relevant tools and independent work. Introduction to scientific theory is to be included, thus anchoring the education in research. The candidate is also to demonstrate a familiarity with relevant methods and ways of working within research and development work. The institution is responsible to providing the students with the proper guidance even when the thesis is performed at an external institution. The course plan is to specify the extent of guidance that will be provided.

NRT has already developed guidance for undergraduate thesis assessment. The revised Regulations have not made changes to this guide until now. Assessment is to emphasize:

- Originality
- The candidate's ability to work independently and stay informed of relevant international literature.
- Clarity, organization, form, structure, and language.
- Use of methods.
- In what way the results are presented in relation to the problem.
- Investigation, relevant theoretical methods or studies supported by research results, independent analysis and reflection.
- Critical self-evaluation.
- The relationship of the conclusion to the problem addressed.

In order to assess each candidate properly, at least one component of the assessment must be performed individually, such as an oral presentation.

7 International Standards

Industry, professional engineering organizations, and engineering institutions develop standards or criteria to help define what constitutes as a good Engineering Education across nations. Examples are:

- European Accreditation or Engineering Programmes (EUR-ACE): Framework Standards for the Accreditation of Engineering Programmes.
- The Quality Assurance Agency for Higher Education, United Kingdom: Subject benchmark statement, Engineering.
- European Society for Engineering Education (SEFI): Common curriculum and course plans for European Engineering Mathematics.
- Engineering Council, United Kingdom: Accreditation by EUR-ACE.
- Accreditation Board for Engineering and Technology (ABET): Accreditation of technological education.

Links to these examples are listed under References (Appendix 8).

Mathematics in Engineering Education is most often uniform across nations. This is also true for basic knowledge and skills within each discipline.

Institutions are expected to offer educational programmes that are internationally approved. This requires each institution to keep up with international trends, standards, and criteria for Engineering Education in general and for each specific discipline.

8 Admission Requirements

There are several requirements for admission to an Engineering Education (cf.: Section 4-4 in Regulations relating to admission to higher education (FOR-2007-01-31-173)):

- Higher Education Admission Qualification, Mathematics (R1+R2), and Physics I.
- Higher education Admission Qualification and completed 1/2 –year natural science course.
- 2-year technical vocational school after National Curriculum approved by the Ministry 1998/99 and earlier programme requirements.
- Newly approved technical vocational education including documented knowledge in mathematics and physics equivalent to Mathematics (R1+R2) and Physics I.
- Completed 1-year preliminary course and maritime university college education.

For applicants to the Three-Semester Programme (TRESS), the requirements are (cf.: Ministry of Education and Research's Notes on National Curriculum for Engineering Education, para. 7, page 3):

Higher Education Admission Requirements

For applicants to the VET Pathway (specifically arranged Engineering Education based on craft certificate) requirements are established in Section 3-3 and Section 4-4 in the Admission Regulations (cf.: Regulations for National Curriculum for Engineering Education, Section 3, last para.):

Relevant craft certificate and a minimum of 12 months relevant practical training.

Link to Admission Regulations for Higher Education:
http://www.regjeringen.no/upload/KD/Rundskriv/2010/Rundskriv_F_15_10_Vedlegg_forskrift_opptak_hoeyere_utdanning_oppdatert_301110.pdf

Admission to Engineering Education is described in Appendix 6.

9 Transition to MSc Studies

National Council for Technological Education has developed and agreed upon a national transfer arrangement. The arrangement was approved 15 May 2013.

The transfer arrangement applies to bachelor's degree candidates in Engineering after the National Curriculum 3 February 2011 who are continuing on to a master's education (sivilingeniør)[3] in technology. The model applies to continuation to both the two last years of 5-year integrated master's education and to 2-year master's education within the same discipline. The model allows for each student to achieve the necessary qualifications regardless of where he/she will get their master's degree. The model includes requirements for physics, mathematics, and statistics.

Information regarding what "MSc Engineering Education" are offered by an institution – as well as possibilities of continuation – should be described in the institutions' informational packets.

The characteristics of an MSc Degree in Engineering are described on NRT's website.

Considering that the institutions are responsible of organizing, distributing, and integrating their courses, setting absolute requirements for covering the leading learning outcomes is challenging. Institutions offering graduate degree education must display lenience when approving undergraduate degrees from other institutions. NRT has pointed out that if one considers degree of coverage in percentages, 80% is a minimum that must be covered.

When elective courses totalling a minimum of 10 credits are developed in order to satisfy the learning outcomes for continuation to graduate studies, the institutions must ensure that candidates who choose to include graduate degree educational requirements in their study, but who do not continue on to a graduate education, are to still be granted a full 3-year bachelor's degree in Engineering. In some cases, disciplines require specific courses in addition to the national model in order to complete a graduate degree. If students who have to enrol in such courses do not become qualified engineers, these courses must be completed in addition to the Engineering Education. The institutions offering the graduate degree education must, possibly in collaboration with the undergraduate institution, ensure that relevant and necessary offers exist so that these students are able to complete their graduate degrees within two years.

Any additional requirements than those established in the National Curriculum, are possible to cover by relevant elective undergraduate courses, relevant and necessary courses at another institution, flexible education, online education, or summer sessions. The requirements may also be completely or partially covered in the regular undergraduate education.

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[3] In order to establish the use of sivilingeniør as an additional title on the graduate diploma, KD suggests changing the degree regulations.

In order to approve an undergraduate education, the institution must make sure each study programme covers 80% of the given learning outcome descriptors, and that typical content, scope, and teaching aids are in compliance with this chapter. Once this is cleared, the undergraduate institution will inform relevant graduate institutions; this arrangement is based on trust. Graduate institutions will rarely require documentation; documentation may be required in cases where candidates from one institution are significantly less qualified than candidates from other institutions over a longer period.

Should a student wish to continue on to graduate studies that have no academic correlation, additional academic requirements may be needed.

Graduate education other than Civil Engineering Education in mathematics, natural sciences, or technology do not apply to the national model. If needed, relevant institutions may develop their own undergraduate to graduate studies arrangements.

The learning outcome descriptors describe those qualifications a candidate is to have achieved after completing their bachelor’s degree and upon applying for graduate studies. The learning outcome descriptors do not apply to single subjects. Particularly qualifications in skills and general competencies are gained by using physics, mathematics, and statistics as tools in other courses. The institutions must remember this when making sure their study programmes cover at least 80% of the academic requirements for continuation.

Learning Outcome Descriptors and Supplementary Text Relating to Physics
Physics is a science that explained how technology is constructed and how it works. Good knowledge of physics is important for every engineer and lays a foundation for engineering as a whole.

Knowledge in physics is not only the basis for technology development; it is also a key factor in understanding and developing a discipline. Physics comprehension and skills in modelling observable phenomena based on basic physics principles allow the candidate to develop creative solutions for practical problems. Knowledge in physics also aids the candidate in handling challenges concerning technology and society. The interplay between physics and the disciplines must be emphasized, particularly the correlation between basic theory and practical training. The interplay between physics and other subjects should also be viewed from a social perspective.

Knowledge in physics is an important enabler for lifelong learning and promotes Engineering Education as well as general education.

Leaning Outcomes
Knowledge

1. The candidate is familiar with basic principles and scientific methods in physics and how physics relate to his/her discipline.
2. The candidate is familiar with basic principles and concepts in mechanics, dynamics, electricity and magnetism, fluid mechanics, thermal physics, waves and oscillations, and has good knowledge of at least one of these topics.
3. The candidate is familiar with the laws of physics and how they may be used to model observable phenomena, and comprehends the validity of the model.

Skills

1. The candidate has the foundation and methodical comprehension that may be applied in subsequent courses, as well as the necessary competence to read professional subject material relating to his/her discipline.
2. The candidate is able to explain basic phenomena in physics and use these to explain problems in engineering using relevant concepts and formulas.
3. The candidate is able to perform practical work in the basic physics topics and masters relevant methods and tools including basic skills in laboratory work, reporting, and presentation of results with uncertainty analysis.
4. The candidate has quantitative problem-solving skills and is able to model by using basic principles of physics, and collect, analyse, and present numerical data.

General Competencies

1. The candidate recognizes the correlation between basic phenomena in physics and practical applications, and understands the function of physics in his/her discipline.

2. The candidate understands the world around him/her and the role physics plays in the interplay between technological development and society, as well as environmental and ethical challenges today and in the future.
3. The candidate understands problems, ways of thinking, methods, and solutions in physics, and is able to communicate these orally and in writing by using appropriate terminology.

Learning Outcome Descriptor Instructions

Technological development is unstoppable. People today are surrounded by technology and new technological products throughout their lives. Physics is a fundamental pillar in many of these products. In Engineering Education it is therefore important to understand the laws of physics. It is also important that the correlation between the basic principles of physics and technical concepts in engineering are made clear. Physics education is adapted to complement each discipline, both in terms of theory and applications. Through learning about physics, the candidate is to develop an understanding of physics as a scientific discipline, various physical phenomena, and ways of thinking and methods in natural science.

Both traditional and modern physics are included in the Upper Secondary course 'Physics I,' on which physics courses in Engineering Education should be based, emphasizing technological applications. Physics subjects must include a consolidation and emphasis of the students' knowledge in classic and modern physics. Basic mechanics such as speed, acceleration, forces, and Newton's laws of vectors; energy, effect and laws of conservation, rotation of rigid bodies may be covered under physics or specialized subjects. The necessity must be seen in correlation to the programme's courses.

Academic institutions must ensure that each undergraduate candidate has the necessary qualifications in physics in order to continue on to graduate studies and thus qualify for a sivilingeniør title. For these candidates, the following components are recommended: mechanics, dynamics, electricity and magnetism, fluid mechanics, thermal physics, waves and oscillations are to all be covered; one of these should be covered more extensively.

The physics component in Engineering Education should total a minimum of 10 credits. Each institution must ensure that the amount of physics is sufficient (80%) in order to qualify for graduate studies.

The following content in physics is recommended (topics mentioned in the National Curriculum are to be included). At least one topic is to be addressed at a specialized level:

Fluid mechanics: pressure, buoyancy, Bernoulli's principle and applications, viscosity. Electricity and magnetism: electrostatics, magnetism, electromagnetic induction, electrical circuits. Depending on discipline, one may also include semiconductor technology; diodes, transistors, amplifiers, photoelectric effect, ionizing radiation.

Mechanics: point particle dynamics, statics and dynamics of rigid bodies, conservation laws for energy, momentum, spin dynamics: kinematics, Newton's laws, work and energy.

Waves: oscillations, resonance, mechanic waves, sound waves, light.

Thermal physics: temperature, thermal expansion, internal energy, heat capacity, entropy, the laws of thermodynamics, kinetic theory of gases, heat transfer (convection, radiations, diffusion).

Examples of textbooks demonstrating the levels and scope of the above mentioned topics:

- Sears and Zemansky's University Physics (Young and Freedman), Pearson
- Physics for Scientists and Engineers (Tipler and Mosca), Freeman
- Generell fysikk for universiteter og høgskoler, vols. 1 and 2 (in Norwegian), Universitetsforlaget (not applicable in terms of vectors)
- Cutnell and Johnson: Introduction to Physics

Both the learning outcomes and the minimum requirement of 10 credits in physics can be achieved in several ways. One possibility is to create specialized courses in physics (10 credits) or offering physics in combination with other natural science subjects in addition to an elective course in physics (5 credits). It is also possible to combine physics subjects with the main subjects.

Learning Outcome Descriptors and Supplementary Texts Relating to Mathematics

Transition to Graduate Studies

Mathematics plays many essential roles in Engineering Education. The subject is a key factor in identifying, formulating, and solving problems in engineering. Mathematics improves academic communication between technology fields, nationally and internationally. From a lifelong learning perspective, basic mathematical skills lay the foundation for innovation, new approaches, and development of mathematics-based competencies. A solid basis in mathematics is thus a pillar in both academic and professional engineering. The learning outcomes must therefore include logical argumentation and basic theoretical and practical understanding of concepts and ideas, as well as knowledge of and skilled use of established techniques and methods.

Engineering mathematics is often uniform internationally. The Regulations state that mathematics is to have an internationally comparative level. (Work is being done in addressing the issue of a qualifications-based description of mathematical subjects in Europe. This is task of the Mathematics Working Group in the European Society for Engineering Education (SEFI).) It is important that each institution remains informed about international work in mathematics in engineering.

In order to achieve the learning outcomes, the revised National Curriculum requires varied ways of working and forms of assessment. Mathematics courses should highlight this. Below are lists of various ways of working and forms of assessment applicable to mathematics courses. It is imperative that the students practice their calculation skills and are able to make those evaluations necessary to solve a complex equation or a practical problem. Didactic literature in mathematics notes that explaining your reasoning is a way of working that promotes mathematical comprehension (Grønmo et al., 2010).

An engineer will often solve mathematical problems with computers; academic mathematics should therefore include a clear calculation perspective that highlights a basic understanding for the possibilities and limitations of analytical and calculation-solving techniques. If students are taught programming in other courses, practicing this actively in mathematics as well is ideal. The focus should not be on skills in specific software, but rather on basic knowledge of mathematical problem-solving using algorithms even if the instruction is often based on such software. A creative use of calculations equals a good understanding of traditional mathematics and good skills in elementary algebra. Early incorporation of calculation perspectives will expedite the incorporation of realistic examples both in mathematics and in mathematics-related subjects.

An Engineering Education is to include a minimum of 20 credits in mathematics. Of these, a minimum of 10 credits are to be common courses for all study programmes, while 10 credits may be tailored to each specific study programme. A minimum of 5 credits in advanced mathematics as part of the elective courses may be offered to help facilitate transition into graduate studies.

Even though the scale and scope of mathematical topics is too significant to cover in 20 credits, mathematical topics and thorough practice of mathematical skills should be covered as broadly as possible in all study programmes. Mathematics is to be actively repeated in technological courses and in relevant interdisciplinary contexts in order to achieve the total learning outcomes.

Transition into graduate sstudies requires a particular scope and level of mathematical subjects depending on the study programme; this is why the number of required credits is tentative. Within each mathematical programme, the main topics mentioned below may be included.

The following list of academic topics is relatively vast. It is important that at least one of the topics is emphasized. The learning outcomes in mathematics are to be achieved during the course of undergraduate study, which may allow for emphasis in other subjects than those purely mathematical as well. Use of mathematics in technical subjects will help strengthen skills and general competencies in some of the subjects. When choosing what topic to emphasize, one should review the entire content of each study programme.

First degree, 25 credits:

Calculus

> Functions; derivation; integration; differential equations; complex numbers, sequences, and series; modelling, numerical calculation methods.
>
> Taylor- and Fourier series, Laplace transformation, exponential series, functions of several variables.
>
> Space curves, integrals, Stokes and Green's divergence theorem, vector analysis, numerical calculation methods, partial differential equations, modelling.

Examples of textbooks demonstrating level and scope of the above-mentioned components:

Calculus (Adams), *Kalkulus* (in Norwegian) (Lorentzen et al.), *Engineering Mathematics* (Anthony Croft et al.), *Matematiske Metoder 1, 2 og 3* (in Norwegian) (Kleive).

Introduction to Linear Algebra

Linear equation systems, matrix algebra, vector space, transformations, eigenvalues and eigenvectors.

Examples of textbooks demonstrating level and scope of the above-mentioned components:

Diskret Matematikk og Lineær Algebra (in Norwegian) (Kleive and Frisvold), *Elementary Linear Algebra* (Edwards and Penney).

Introduction to Discrete Mathematics

Combinatorics, logic, set theory, induction.

Examples of textbooks demonstrating level and scope of the above-mentioned components:

Diskret Matematikk og Lineær Algebra (in Norwegian) (Kleive and Frisvold), *Discrete and Combinatorial Mathematics* (Grimaldi), *Discrete Mathematics and Its Applications* (Rosen).

At least 80% of these topics must be covered in a bachelor’s degree.

Emphasis in linear algebra, complex function theory, partial differential equations, and discrete mathematics is added to graduate studies within the relevant specializations.

Learning Outcomes

Knowledge

1. The candidate has developed a basic academic understanding of mathematics on which other subjects can build, which also lays the foundation for lifelong learning.
2. The candidate has knowledge of basic mathematical applications in engineering.
3. The candidate has knowledge of problem-solving and modelling to solve problems in engineering.
4. The candidate has extensive knowledge of core subjects such as derivation, integration, differential equations, matrixes, vector space and eigenvalues/vectors in linear algebra.

5. The candidate has knowledge of complex numbers, functions of several variables, exponential series, difference equations, numerical calculations and their possibilities and limitations.

Skills

1. The candidate is able to make use of a relevant mathematical symbol and formula apparatus.
2. The candidate is able to recognize, understand, and use basic mathematical concepts.
3. The candidate is able to reason mathematically and make logical inferences.
4. The candidate is able to articulate problems in engineering in a mathematical way and is able to evaluate results from mathematical calculations.
5. The candidate is able to solve problems using both analytical and numerical methods.
6. The candidate has good calculation skills.
7. The candidate is able to identify mathematical applications in engineering within his/her discipline including the use of numerical calculations.

General Competencies

1. The candidate is able to use mathematics to communicate problems in engineering.
2. The candidate understands that the level of precision in the mathematical language is what makes it eligible to structure problems in engineering and to find solutions.
3. The candidate is familiar with analytical ways of thinking and is able to recognize correlations between relevant mathematical concepts.
4. The candidate has mathematical comprehension as a foundation for lifelong learning.

Organization and Ways of Working

Lectures, calculations, colloquiums, take-home assignments with and without technological aids, written individual and group projects with oral presentations. Problem-based learning and use of technological aids.

Relevant Literature, Professional Subject Matter, and Sources

Textbooks such as *Calculus* (in Norwegian) (Lorentzen et al.), *Matematiske Metoder 1, 2 og 3* (in Norwegian) (Kleive), *Calculus* (Adams), *Engineering Mathematics* (Anthony Croft et al.), *Diskret Matematikk og Lineær Algebra* (in Norwegian) (Kleive and Frisvold), *Elementary Linear Algebra* (Edwards and Penney), *Discrete and Combinatorial Mathematics* (Grimaldi), *Discrete Mathematics and Its Applications* (Rosen).

Work Requirements

Mandatory calculations and/or mandatory submissions.

Assessment/Exams

Assessment of each course must be adapted to the learning process and different forms of assessment may be applicable: written final examination, oral examination, portfolio, individual oral test, practical test, written test. A portfolio may include several forms of assessment; written final examination, continuous assessment, mandatory individual or group reports, projects. If a final grade is based on more than one form of assessment, each assessment must be passed, and individual assessment will be included.

Learning Outcome Descriptors and Supplementary Text Relating to Statistics
Good knowledge of statistics lays an important foundation for graduate courses in several disciplines and for taking advanced statistics courses—a natural component in many graduate programmes. Knowledge of statistics is also important in terms of general education.

Learning Outcomes

Knowledge
1. The candidate is familiar with the way statistics provides him/her with the necessary tools for describing and evaluating test results and other data, and for describing and handling uncertainty.
2. The candidate is able to interpret descriptive statistics.
3. The candidate is familiar with basic probability theory and central probability distributions.
4. The candidate is familiar with the theoretical basis for estimation, confidence intervals, and statistical hypothesis testing.

Skills
1. The candidate has the necessary basis for reading professional subject matter relevant to his/her discipline.
2. The candidate is able to use statistical principles and concepts within his/her discipline.
3. The candidate is able to collect, analyse, and present numerical data.
4. The candidate masters basic probability calculation and is able to estimate, conduct statistical hypothesis testing and simple correlation/regression analyses.
5. The candidate is able to use the appropriate software.

General Competencies
1. The candidate is able to use statistical surveys and methods to acquire relevant answers to problems in engineering.
2. The candidate comprehends statistical methods and ways of thinking and is able to communicate these orally and in writing.
3. The candidate is able to apply statistical thinking and probability calculation to evaluate technical, economic, ethical, and legal challenges.

Learning Outcome Descriptor Instructions
Relevant topics in statistics are the same for all disciplines, and are meant to extend statistic courses from Upper Secondary School. Descriptive statistics should include central tendency and dispersion and simple graphic illustrations. Topics typically covered in probability calculation include: introduction to the probability concept; conditional probability; random variable; probability distribution; expectation and variance; binomial, Poisson, hypergeometric, normal, and exponential distribution; and the central limit theorem. Statistical analysis should include estimation, confidence interval, and statistical hypothesis testing in normal and binomial distribution, effect size, and introduction to correlation and linear regression.

The many uses of statistics in engineering should be highlighted through various examples. Statistics are also important in terms of general education and for everyday applications. Social sciences and risk and reliability should also be discussed.

Examples of textbooks demonstrating the level and scope of the above-mentioned components include: *Probability and Statistics* (Walpole et al.), *Statistikk for Universiteter og Høgskole* (in Norwegian) (Løvås).

10 Measures for Collaboration, Division of Labour, and Academic Concentration (SAK)

In the ongoing implementation work, SAK will be in focus. Meetings will be a tool for discussion and understanding of the collaborative academic elements, of which professional concentration or division of labour is natural.

During the development of the learning outcome descriptors for Civil Engineering, Computer Engineering, Electrical Engineering, Chemical Engineering, and Mechanical Engineering, the importance of common learning outcomes for each discipline nationally was emphasized (this is reflected in common courses and programme courses), but also the importance of making room for each candidate to specialize within his/her discipline (technical specialization courses). The learning outcome descriptors for each discipline are designed in a way that allows for division of labour and academic concentration. Elective courses allow for each institution to specialize, which gives the institution a national or regional advantage in terms of industry structure, basis for recruitment, and resources.

To prompt binding agreements concerning SAK, the senior management of each institution must be engaged in the processes.

NRT will work on developing this chapter in time for the next edition of Guidelines. The revised version will consider the experience gained through the resources currently used on SAK. The experience resulting from the National Curriculum, Guidelines, and implementation of SAK-projects will be important in the institutions' further work on SAK and NRT's development of this chapter.

Appendices

Appendix 1 Definitions

Field of Study, Discipline, and Engineering
The Regulations use the concepts *field of study, discipline,* and *engineering subjects.*

Field of study in technological educations usually refer to a chosen programme option/specialization within a discipline; for instance, the **discipline** Electrical Engineering includes fields of study such as high voltage, low voltage, cybernetics, telecommunications, medical technology, and avionics. These technical subjects that make up the field of study.

Engineering (the profession) includes technical subjects with necessary basic subjects such as mathematics, physics, chemistry, statistics, social science, and economics; the subjects are viewed systemically. Work methodology such as new approaches, problem identification, articulation of problems, analysis, specification, generating solutions (synthesis), evaluation (also includes impact assessments), choices, reporting, and realization/entrepreneurship.

Programme plan and course plan
a description established by the boards of each institution based on the National Curriculum, is called a **programme plan.** The **course plans** are based on the programme plan and relevant learning outcomes.

Appendix 2 Suggestions for Interpreting Learning Outcome Descriptors

Knowledge

LU-K-1: The candidate has broad knowledge that provides an integrated systems perspective of engineering in general, with specialization in his/her own engineering subject.

This qualification is the corner stone of this education, and is to, along with LU-K-2, represent the key element of the education's professional orientation and provide necessary professional knowledge for developing skills and general competencies. Systems analysis and synthesis are industry's fundamental requirements of the engineers of today and tomorrow. The undergraduate thesis is an important contribution to fulfilling this learning outcome.

LU-K-2: The candidate has basic knowledge of mathematics, natural science, relevant social science and economics subjects, and about how these can be applied to problem-solving in engineering.

Mathematics, physics, chemistry, statistics, social science, and economics are essential tool subjects that lay the foundation for understanding and applying to technical subjects. Knowledge in these traditional subjects, supplemented with a computational perspective through the help of computers, lays an important foundation as a professional engineer and to acquire necessary new knowledge post-education. Analytical orientation and being able to use mathematics as an analytical tool is a central requirement of engineers today and tomorrow.

LU-K-3: The candidate has knowledge of the history of technology, the development of technology, the engineer's role in society as well as the consequences of the development and use of technology.

Technological development is closely correlated to developments in physics and chemistry; society is thus continuously shaped by innovations in technology. Technology affects us both in terms of work and leisure, childhood, adolescence, adulthood, and old age; all professions and occupations depend on technology. Universal design considers the difference between users, and similarly to health, environment, and safety (HES), is essential in engineering. As technology can be used both in good and in less good ways, having conscious engineers is crucial. The engineer plays an important role in society, and has both a significant ethical and a social responsibility. Engineers must have a thorough understanding of their social role and influence.

LU-K-4: The candidate is familiar with research and development work in his/her own field, as well as relevant methods and ways of working in engineering.

Society is constantly changing and research plays a key role in this process. Education is a central part of life as values are gained and developed. Critical, reflective, and conscious thinking is stimulated through education based on research, as well as knowledge of scientific methods and ways of working in engineering. Use of algorithm and mathematical calculations with computers is paramount. Students that are able to take part in research and development work during their education gain a better understanding of research and development work.

LU-K-5: The candidate is able to update his/her knowledge of the field, both by gathering information and through contact with professional communities and practical work.

Continuous search for updated knowledge, both theory and practice, through different sources, is essential when practicing engineering. To seek knowledge – lifelong learning – is an important post-degree qualification.

Skills

LU-F-1: The candidate can apply knowledge and relevant results of research and development work to solve theoretical, technical, and practical problems in engineering and be able to give reasons for his/her choices.

Professional engineering consists of a plenitude of various tasks including new approaches, problem-articulation, analysis, specification, generating solutions such as calculations, evaluation, choice, and reporting. Skills to execute tasks such as these are developed through application of acquired knowledge in active learning processes and problem-based learning during the students' education.

LU-F-2: The candidate is has digital skills in engineering subjects, is able to work in relevant laboratories, and masters methods and tools as a basis for goal-oriented and innovative work.

Engineering applies science, technology, and social science subjects to specific and practical problems. Exposure to both theory and practice, and the ability to recognize their interconnectedness, promotes motivation and learning. The students must acquire skills in using relevant professional methods, tools, and technological aids to practice engineering. They must be able to develop tools based on known methods. Goal-oriented work includes both analytical and structured work.

LU-F-3: The candidate is able to identify, plan, and carry out engineering projects, tasks, trials, and experiments both independently and in teams.

Collaboration across disciplines and in a broad perspective is needed in order to achieve good solutions. Whether the tasks are completed as part of larger projects or smaller projects, the engineer must work well independently and in teams. The profession demands the ability to recognize possibilities and act on them (innovation and entrepreneurship).

LU-F-4: The candidate is able to find, evaluate, use, and refer to information and professional subject matter and present this in a manner that focuses on a problem.

Active and critical use of various sources is an absolute necessity for research-based education, and essential for educating responsible and ethically conscious engineers. Quality control, safety, and risk analysis are central to the engineer and demand practice of critical and analytical skills. Different sources include research articles, textbooks, webpages, databases, resource people, etc.

LU-F-5: The candidate can contribute to new approaches, innovation, and entrepreneurship by developing and realizing sustainable and socially useful products, systems, and/or solutions.

Knowledge in engineering is made visible when new solutions and innovations are developed and realized, and new business opportunities are created and established (entrepreneurship). An environmental focus may challenge the students' abilities of new approaches and innovation, as well as their skills in developing, evaluating, and realizing new products, systems, and solutions in a comprehensive and socially valuable perspective.

General Competencies

LU-G-1: The candidate has insight into environmental, health-related, social, and financial consequences of products and solutions in his/her field, and is able to put these into an ethical perspective and a life cycle perspective.

An engineer's tasks are usually components of a larger unit – a system. The way limits are set in this system affects the way the task is solved. Narrow limits imply that function is a sole concern. Further limits demands that the engineer views his/her solution in relation to people (users and operators), society and environment. Working in a systems perspective requires collaboration between several professions. Future engineers must have an insight into this comprehensiveness, at the same time as they must recognize each separate component in a technological solution. Rapid technology development and information flow make systems thinking and a sense of comprehensiveness into a central part of the engineer's work.

LU-G-2: The candidate is able to communicate knowledge of engineering to different target groups, both in writing and orally in Norwegian and in English, and is able to contribute to making visible the significance and consequences of technology.

Shared knowledge is a stipulation for development. Communicating knowledge to peers and others is important. Today's globalized world demands that communication typically occurs in a foreign language, through different channels, and with an understanding for other cultures. Communication tools may be oral, written, digital, and visual (reports, research articles, popular natural science articles, posters, featured articles, social media, computer tools, and other technological solutions/tools. Several businesses operate in an international market and use English as a working language.

LU-G-3: The candidate is able to reflect on his/her own academic performance, also in teams and in interdisciplinary contexts, and is able to adjust to the relevant work situation.

Many tasks in engineering require collaborative efforts across disciplines and on a larger interdisciplinary scale. To ensure collaborative success, consciousness of personal knowledge and skills is necessary, as well as respect for other fields of study and professionals.

LU-G-4: The candidate is able to contribute to the development of good practice by taking part in academic discussions in the subject area and share his/her knowledge and experience with others.

Good professional qualifications are required to participate in professional discussions, and to contribute to the development of good practice in an ethical and eco-friendly way; this requires practice. Sharing knowledge and experience is central for bettering professional qualifications.

Appendix 3 Expansion and Specification of Learning Outcomes for Social Sciences

The task group that developed suggestions for the learning outcome descriptors for social sciences included representatives from the institutions, industry, and the student body. The task group also elaborated on and specified central elements of learning included in each learning outcome descriptor. These are flexible and the institutions may choose to develop learning outcome descriptors in collaboration with relevant professionals and the students.

Knowledge

a) The candidate has knowledge of the roles of technology and engineers in social development. This requires that the candidate:
    - Has a historical and future-oriented perspective of technology's impact on social development nationally and internationally.
    - Understands that people develop technology and that technology affects people.
    - Is familiar with the significance of technology in the work to solve environmental and climate challenges.

b) The candidate has knowledge of professional rules and interactions. This requires that the candidate:
    - Is familiar with Health, Environment, and Safety (HES) as a basis for a good work environment.
    - Has knowledge of relevant rules and agreements and the intentions behind these; this also includes employee and employer rights and duties.

c) The candidate has basic knowledge of business organization, value creation, productivity, and profitability. This requires that the candidate:
    - Is familiar with how businesses are organized in terms of corporate and company units, and in terms of function, market, and projects.
    - Has knowledge of basic management theory.
    - Is familiar with the way businesses create value in terms of their stakeholders – focusing particularly on employers.
    - Is very familiar with the different definitions of profitability from business economic and social economic perspectives.
    - Has knowledge of market analyses and how a market's need for products and services affect demand, prices, income, and profitability.

d) The candidate has basic knowledge of business economics. This requires that the candidate:
    - Understands the most important areas in business economics: preparation and analysis of financing, cost calculation and pricing, basic methods of business economic analysis, and profitability assessments of investments.

e) The candidate has knowledge of innovative processes and entrepreneurship. This requires that the candidate:
    - Has knowledge of innovation and innovative processes and what it means to meet the increasing demands for change and adjustment, both in industry and management, and how this increases value creation and productivity.
    - Understands the correlation between development and improvement of technical products and services, and organizational changes, management forms, and professional collaboration.

    - Has basic knowledge of entrepreneurship in existing and established businesses and recognizes organizational and project structures that stimulate innovation and entrepreneurship.

f) The candidate has knowledge about establishing and executing projects. This requires that the candidate:
    - Has knowledge of how one may manage, organize, and lead project work.
    - Has knowledge of the entire process – from the idea, via planning and executing, to assessment and post-completion work.
    - Is familiar with different forms of team (self-managed, interdisciplinary, and multicultural), different roles (project leader, member, expert), and what challenges this may include, as well as group processes, and collective and individual responsibility.
    - Has knowledge of project finance.
    - Has knowledge of project management tools, reporting, and inter-group communication (oral and written).

Skills

a) The candidate is able to assess profitability and economic risk. This requires that the candidate:
    - Is able to read and interpret accounting data.
    - Is able to calculate cost and set prices.
    - Is able to use basic techniques in business economic analysis.
    - Is able to evaluate profitability and economic risk of investments.

b) The candidate is able to contribute to new approaches, innovation, and entrepreneurship through his/her participation in development and realization of sustainable and socially useful products, systems, and solutions. This requires that the candidate:
    - Masters creative techniques and has an experimental attitude so that he/she may contribute to innovative and entrepreneurial endeavours.
    - Is able to recognize economic, organizational, and social consequences when he/she develops technical solutions so that the technology becomes part of a sustainable and socially useful development.

c) The candidate is able to communicate orally and in writing about his/her discipline both in Norwegian and in English, and can contribute in interdisciplinary collaborations and in public debates. This requires that the candidate:
    - Is skilled at oral and written communication, scientific writing, reporting and documentation, and is able to use sources and references effectively and correctly.
    - Is able to express him/herself to peers in Norwegian and English.
    - Is able to define goals and achievements.
    - Is able to collaborate and effectively communicate in groups.

General Competencies

a) The candidate is able to initiate smaller projects, and through proper management, conserve human, professional, economic, ethical, and social considerations. This requires that the candidate:
    - Views the project as part of a unit and is able to use his/her experience from project work and project management to find comprehensive solutions.

b) The candidate is able to recognize an interdisciplinary correlation between economics, management, ethics, society, technology, and the environment. This requires that the candidate:
   - Has a profession-wide understanding of the significance of technology and is able to include this in interdisciplinary work.

c) The candidate comprehends the meaning of cultural competencies. This requires that the candidate:
   - Is open to other cultures and dissimilarities, both nationally and internationally.
   - Has knowledge of the most important cultural differences engineers face in places that interact with Norwegian industry.

Appendix 4 Example of Learning Outcome Descriptors for Introduction to Professional Competencies and Ways of Working

Learning outcome descriptors for "Introduction to professional Competencies and Ways of Working" was developed by a task group consisting of representatives from the institutions, industry, and student body. This example is flexible and the institutions may choose to develop learning outcome descriptors in collaboration with relevant professionals and the students. This is defined as its own subject, and the learning outcomes from technology, social science, and natural science subjects have been integrated.

Knowledge

a) The candidate has a basic understanding of professional engineering and the engineer's social and professional role.
b) The candidate has knowledge that lays the foundation for viewing technology both from a historical and a future-oriented perspective.
c) The candidate is familiar with scientific ways of working and has basic knowledge of project work, in terms of organization, execution, and reporting.
d) The candidate is familiar with the basic principles of effective study techniques.

Skills

a) The candidate is able to identify problems in engineering, seek necessary information, and quality assure this as grounds for a solution.
b) The candidate is familiar with basic innovative processes and new approaches in regards to project work.

General Competencies

a) The candidate is conscious of environmental and ethical consequences of technological products and solutions.
b) The candidate is familiar with way he/she can share his/her knowledge and experience with others both orally and in writing, in English and in Norwegian, and is able to work in groups.
c) The candidate is capable of organizing, plan, and executing his/her education, both individually and in collaboration with others.

Appendix 5 Example of Learning Outcome Descriptors for Engineering Systems Thinking

Learning outcome descriptors for “Engineering Systems Thinking” was developed by representatives from the institutions, industry and the student body. This example is flexible and the institutions may choose to develop learning outcome descriptors in collaboration with relevant professionals and the students. This is defined as its own subject, and the learning outcomes from technology, social science, and natural science subjects have been integrated.

Knowledge

a) The candidate has developed a professional basis for and an understanding of modelling techniques.
b) The candidate has developed a professional basis and an understanding of life cycle analyses.
c) The candidate has acquired the necessary knowledge for system definition, sub systems, limitations, systems analysis, synthesis, strategic analysis, and uncertainty analysis.
d) The candidate understands basic correlations between technical singular elements and systemic comprehensiveness.

Skills

a) The candidate has developed skills in systems modelling.
b) The candidate is able to complete systems analysis, design subsystems and synthesis.
c) The candidate is able to communicate results of systems analysis and synthesis.

General Competencies

a) The candidate understands that the interdisciplinary approach is necessary to find good systems solutions.
b) The candidate understands impact.
c) The candidate is able to communicate engineering in a systemic context.
d) The candidate has developed teamwork abilities.

Appendix 6 About Admission Options and Adjusted Engineering Education

Specific admission requirements are the typical admission option in Engineering. Below are some of the alternative admission options. These are to accommodate the revised National Curriculum. The institutions are to collaborate to ensure that students are able to apply to other academic institutions than the institution in which he/she was qualified. Mobility is also to be an option for students who were admitted based on alternative grounds.

Preliminary course for Engineering Education and Maritime University College Education

A preliminary course is offered Upper Secondary School students (level 3 of NKR's draft proposal) and not higher education students. The course is intended for learners who do not have Higher Education Admission Requirements or who have HEER without the required emphasis in mathematics and physics. The course is meant to prepare the learners for an undergraduate study in Engineering. A complete preliminary course for a full-time student is expected to last one year. In order for learners to change academic institution after completing the course, the recognized preliminary course plan must be followed, and the common final examination must be passed.

A preliminary course variant is a natural science course that is offered to students who have a general Higher Education Admission Qualification but who do not have the specific admission requirements. The natural science course lasts one semester.

Student may complete relevant Upper Secondary courses as external candidates.

Preliminary course learners are to be given documentation of those qualifications they have achieved after completing the course. The documentation is to illustrate those qualifications relating to the learning outcomes in the educational programme for specialization under natural science subjects.

The institutions that offer a preliminary course should collaborate on any further development of the course based on the revised National Curriculum. The institution will have to decide how the offer is to be organized as full-time, part-time, further education, or distance learning. The existing collaboration regarding holding examinations through a common examination secretariat is maintained, and offering this to institutions that are not engaged in the collaboration.

Tertiary Vocational Education with Additional Mathematics (R1+R2) and Physics I

A completed vocational degree after previous arrangements satisfies one of the alternative requirements to Engineering Education. For newer technical vocational education, additional requirement of Mathematics (R1+R2) and Physics I is also needed.

Those who have completed a vocational degree may acquire the required learning outcomes in mathematics and physics in several ways:

- Sit for examination in the additional Upper Secondary subjects
- Sit for examination in the relevant subjects as electives, or as additions to vocational education

- Sit for examination in the relevant subjects as part of the preliminary course, the natural science course, or TRESS
- Sit for examination in the relevant courses as part of the VET-pathway

Characteristics of technical vocational education:
The National Committee for Technical Vocational Education has collaborated with industry organizations and developed a recommended "curriculum" that is not binding for the technical vocational education.
http://www.skolenettet.no/moduler/Module_FrontPage.aspx?id=14590&epslanguage=NO.

This education is to include a minimum of:
10 vocational school credits in natural science (6 in mathematics and 4 in physics)
12 vocational school credits in communication (9 in Norwegian communication and 3 in English communication)

The remaining vocational school education must be relevant to a technical education, (technical subjects and supplementary subjects – management, economics, or marketing or natural science subjects. The supplementary subjects may be integrated into the technical subjects. The education should equal two years as a full-time student. Educations that do not satisfy these requirements will not automatically be considered as newer technical vocational school educations.

An approved education is approved by NOKUT under the Act relating to Vocational School Education:
http://www.skolenettet.no/moduler/Module_FrontPage.aspx?id=14590&epslanguage=NO
The government regards Accreditation of Prior Experiential Learning as the main principle for recognition of vocational school education in higher education. From Proposition to the Storting (Parliament) no. 1 (2005-2006), page 129: "Credits may be granted to students with documented competence from a vocational school that corresponds to the subject areas of the university or university college's study programmes. The universities and university colleges must assess how this can be done so that the applicants are informed of exemption or reduced scope in the education." The government also stipulates the importance of predictable equality. The institutions will be able to collaborate on what vocational educations qualify for admission and what sort of exemption they may offer. With such a collaborative effort, equal treatment is difficult to guarantee.

The Three Semester System (TRESS)
The qualifying courses in TRESS and the Natural Science Subjects Course are identical in terms of learning outcomes and have virtually the same scope.

The Natural Science Subjects Course and TRESS recruit from the same group of applicants. The TRESS admission requirement is a Higher Education Admission Qualification. In addition to the three regular school years, summer sessions totalling 10-14 weeks are offered. The offer starts during summer. TRESS-students are to have completed and documented the learning outcomes as ordinary students by the start of the second year. The qualifying courses in mathematics and physics are not part of higher education. Completed courses in the first year of TRESS are worth

60 credits. The institutions are to ensure that acquired qualifications in the qualifying courses are documented. TRESS-students will take “Introduction to Professional Engineering and Ways of Working” simultaneously with the other undergraduates. The students follow the ordinary study after the second year.

To accommodate SAK, the institutions should collaborate on arranging TRESS and the qualifying courses. The preliminary course, the Natural science Subjects Course, and TRESS include the qualifying courses mathematics and physics. These courses may have similar content independently of arrangement; the courses may be offered as flexible education.

VET-Pathway

Institutions that offer the VET-pathway must clarify what craft certificates are relevant (cf. Section3-3 in Regulations relating to admission. According to the consultation letter regarding the National Curriculum, “The ministry states that there should be no discrimination regarding the way a craft certificate was earned.” Institutions offering the VET-pathway must thus clarify how they intend to treat those who earned their craft certificates via Section 3-5 in the Education Act – practical candidates. According to the notes in the National Curriculum: “Students who are accepted via the VET-pathway cf. Section 3-3 in the Regulations relating to admission to higher education, have passed technical subjects in their vocational education that, along with professional practical training, may grant exemption from up to 30 credits in the Engineering Education.” The practical training must be relevant and must have lasted a minimum of 12 months. The extent of exemption will therefore be predictable, but assessed individually. Applicants to the VET-pathway should be ensured a national standard in terms of exemptions.

Section3-3 in the Regulations relating to admission does not apply to vocational educations that result in vocational competencies. Information given to applicants and the plan prescribed by the institution must include what craft certificates are relevant for admission.

The necessary qualifications in general courses at an Upper Secondary level in Norwegian, mathematics, and physics do not grant credits. The institutions are to ensure that acquired qualifications in the qualifying courses – Norwegian, mathematics, and physics – are documented.

Meeting the Mathematics and Physics Qualifications

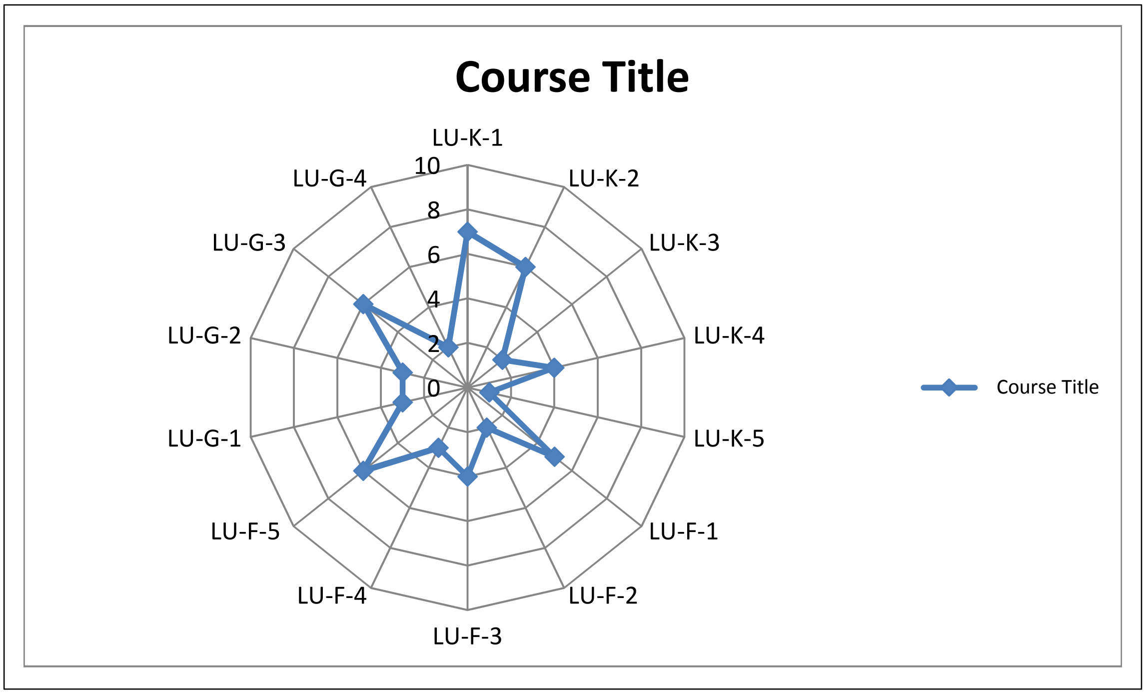
General admission requirements in mathematics and physics may be achieved in several ways:

- Sit for examination in Mathematics (R1+R2) and Physics I in Upper Secondary School
- Sit for examination in the relevant subjects as electives, or as additions to vocational education
- Sit for examination in the relevant subjects as part of the preliminary course, the natural science course, or TRESS
- Sit for examination in the relevant courses as part of the VET-pathway

Appendix 7 Example of Tools – Radar Charts and Matrices

The emphasis of learning outcomes in a course can be visualized in a radar chart. An Excel-based diagram may be used.

Radar Chart



Matrix

Another useful tool is a matrix. Qualifications are listed along one axis and courses/course groups along the other axis. The example below illustrates how each course meets the learning outcomes.

	Course xx	Course yy	Course zz	…..	.....	…..	Course ww
LU-K-1	X		X				X
LU-K-2		X	X				X
LU-K-3	X	X	X				X
LU-K-4		X	X				X
LU-K-5	X						X
LU-F-1	X		X				X
LU-F-2	X						X
LU-F-3	X						X
LU-F-4			X				X
LU-F-5		X					X
LU-G-1	X						X
LU-G-2			X				X
LU-G-3	X	X					X
LU-G-4		X	X				X

Appendix 8 References, Literature, National Public Documents, and Websites

- NOKUT 92008): Assessment of Engineering Education: http://nokut.no/no/Norsk-utdanning/Kvalitetsutvikling-gjennom-utredning-evaluering-og-analyse/Evaluering-for-a-bedomme-kvalitet/Avsluttede-evalueringer/Evaluering-av-ingeniorutdanning
- NOKUT: Regulations relating to supervision of academic quality in higher education (The Supervision Regulations): http://www.nokut.no/Documents/NOKUT/Artikkelbibliotek/Norsk_utdanning/Forskrifter_Kriterier_mm/Forskrift_om_tilsyn_med_utdanningskvaliteten_i_h%c3%b8yere_utdanning.pdf
- Mandate for The National Curriculum Regulations Committee and Task Groups: http://www.hio.no/Enheter/Ny-rammeplan-for-ingenioerutdanningen/Mandat
- Grounds for revised National Curriculum Regulations for Engineering Education. The National Curriculum Project, Process, and Defence. 15 June 2010: http://hio.no/Media/Files/Rammeplan-prosess-og-beslutningsgrunnlag
- The National Curriculum Regulations for Higher Education: http://www.regjeringen.no/upload/KD/Hoeringsdok/2010/200905741/UH_Kvalifikasjonsrammeverket.pdf
- Action Plan for Entrepreneurship: http://www.regjeringen.no/nb/dep/kd/dok/rapporter_planer/planer/2009/handlingsplan-for-entreprenorskap-i-utda.html?id=575005
- Government Issued Statement No. 30 (2008-2009): Climate for Research: http://www.regjeringen.no/nb/dep/kd/dok/regpubl/stmeld/2008-2009/stmeld-nr-30-2008-2009-.html
- Government Issued Statement No. 44 (2008-2009): Education Programmes: http://www.regjeringen.no/nb/dep/kd/dok/regpubl/stmeld/2008-2009/stmeld-nr-44-2008-2009-.html
- Government Issued Statement No. 16 (2006-2007)…and None Were Left Hanging – Early efforts for Lifelong Learning: http://www.regjeringen.no/nb/dep/kd/dok/regpubl/stmeld/2006-2007/stmeld-nr-16-2006-2007-.html?id=441395
- NOU 2000:14 Freedom with Responsibility: http://www.regjeringen.no/nb/dep/kd/dok/regpubl/stmeld/2006-2007/stmeld-nr-16-2006-2007-.html
- From Berlin to Bergen and Beyond: www.bologna-bergen2005.no/
- The Dublin Descriptors: www.jointquality.nl/content/descriptors/CompletesetDublinDescriptors.doc
- The European Qualifications Framework: http://ec.europa.eu/education/pub/pdf/general/eqf/leaflet_da.pdf
- Enhancing Creativity and Innovation, Including Entrepreneurship, at All Levels of education and Training – EU 2010: http://ec.europa.eu/education/lifelong-learning-policy/doc/report09/chapter4_en.pdf
- Grønmo, Liv Sissel, Onstad, Torgeir and Pedersen, Ida Friestad (2010): Matematikk i Motivind, TIMSS Advanced 2008 in Upper Secondary School. Oslo. Unipub.
- European Accreditation of Engineering Programmes (EUR-ACE): Framework Standards for the Accreditation of Engineering Programmes: http://www.feani.org/webfeani/EUR_ACE/eur-ace%202/P1%20EUR-ACE_Framework%20Standards%2028.08.08.pdf

- Benchmark Engineering: http://www.qaa.ac.uk/academicinfrastructure/benchmark/statements/Engineering06.pdf
- European Society for Engineering Education: http://www.sefi.be/
- Engineering Council (United Kingdom): http://www.engc.org.uk
- Accreditation Board for Engineering and Technology (ABET) (USA): http://www.abet.org