Report

NTNU
Norwegian University of Science and Technology

Key takeaways from visits to ETH, TU Delft, DTU, and Chalmers

Brief report from NTNU Executive Committee for Engineering Education's study tour April, 9th—12th, 2019

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Table of contents

1 Introduction

In mid-April 2019, NTNU's Executive Committee for Engineering Education (ECEE) visited four leading technical universities in Europe. The aim was to exchange ideas and experiences related to engineering education, primarily on the master level but also on the bachelor level.

ECEE were warmly welcomed by all hosting institutions, and we had fruitful discussions on a wide range of topics. All meetings lasted 3.5—4 hours and were packed with clear insights and inspirational discussions. For more info on topics and participants, please see Appendix A—D.

This report aims to summarize the meetings. For each meeting, key points are grouped according to a standardized theme structure for better readability and easier comparisons. Not all themes were discussed at all meetings – hence, the document holds some empty slots. Issues are not explored and discussed in depth -- rather, a concise and fact-oriented format has been chosen.

In line with the spirit of sharing that we encountered on our tour, we think it is only appropriate to share our takeaways with all the four institutions we met. Three of the institutions have also fact-checked their specific chapters. Hopefully, the document can serve as a simple reference in discussions on education development at all five institutions involved.

Members of the NTNU ECEE group included:

- Mads Nygård, Dean of Engineering Education, NTNU - Chair of ECEE
- Geir Egil Dahle Øien, Dean Faculty of Information Technology and Electrical Engineering
- Leif Rune Hellevik, Vice-Dean for Education Faculty of Engineering
- Karina Mathisen, Vice-Dean for Education Faculty of Natural Sciences
- Halgeir Leiknes, Chair of FUI, NTNU
- Emilie Wattø Larsen, student, NTNU
- Nils Rune Bodsberg, Secretary for ECEE, NTNU
- Reidar Lyng, Chair of SEED (only ETH and TU Delft)

The entire NTNU group wishes to thank ETH, TUD, Chalmers, and DTU for your hospitality, your time, and your good spirits!

2 ETH

2.1 Key info

University	ETH Swiss Federal Institute of Technology Zürich
Location	Zürich, Switzerland (two campuses). Additional locations in Switzerland and in Singapore.
Type of university	Polytechnical university incl natural sciences. Public. 16 departments.
Number of (engineering and science) students	Bachelor: 9 500 Master: 6 600 Ph.d.: 4 200 *Total: 20 300 (headcount)*
Personnell	Scientific: 6 100 (FTE, thereof 3 700 FTE PhD student/research assistants) Technical/administrative: 2 800
Number of degree programs	Bachelor: 23 Master: 46
Website	https://ethz.ch/en.html

2.2 Student Recruitment

- Admission requirement (bachelor): "Matura" – general high school exam. Special math or science subjects not required (math is a compulsory subject in the "Matura" exam;

preselection of students is not possible. "Open" access means information is key; "selection" of students happens after 1st year.

- Students with a vocational "matura" background can be admitted to Bachelor's degree programmes subject by passing an additional "passerelle" exam. Bachelor graduates from Universities of Applied Sciences ("Fachhochschule") with a certain minimum GPA can be admitted to Master's programme but are required to take addition courses (40-60 ECTS); usually very good students.
- Female students: > 30%, but very unevenly distributed across degree programmes
- Female students have better Matura grades but lower 1st-year grades
- Gender-promoting mechanisms: offered by certain departments with "room for improvement" (Mathematics, Computer Science etc)
- Tuition: 1160 + 150 CHF (= appr 1340 USD) pr year (for national and international students)
- Dropout: >30% after year 1. May try exam once more.

2.3 Program Structure

- Used to have 5-year Diploma program – now 3-year bachelor and 1.5/2-year master (depending on the programme)
- New master programs: Data science; Cyber security; Quantum Engineering

2.4 Teaching

- Emphasis on project-based learning and presentations
- Policy values:
  - Unity of teaching and research (equivalence in status)
  - Unity of knowledge, thought and action
  - Performance orientation (for lecturers and students)
  - Personal responsibility (for lecturers and students)
- Online: MOOCs and TORQUEs (ETH-internal)

2.5 Assessment

- About 10% digital exams, using Safe Exam Browser (SEB)
- Students have only two attempts at any exam, curricula must ensure that there is a possibility for compensation through examination blocks (results of several exams are counted together) or alternative courses (no "killer courses")

2.6 Internships, Relevance

- Many programs have industrial internships integrated; others recommend an optional internship

2.7 Non-Technological Skills

- Digitalization: "Horizontal" skill that must be integrated in the whole study programs
- Alumni surveys indicate that "soft skills" (teamwork; communication; negotiation; management etc) should have more emphasis
- ETH Talent: A system for documenting each student's competencies. Includes skills from extra-curricular activities (student unions etc). Tool support is under development.

2.8 Learning Environment

- Semesters: Bachelor: six; Master's: three or four
- Language: German in bachelor programs; English in master programs
- Growth: Since 2007, 59% increase in number of students while only 18% increase in building area -> infrastructure utilization is a major challenge

2.9 Lifelong Learning

- Strategic focus for ETH
- Strong growth in Continuing Education Master's programs ("Master of Advanced Studies, 60 ECTS) and short courses. Considering micro degrees.

2.10 Entrepreneurship

- ETH Week: A week with student projects
- ETH Singapore month
- ETH Student project house:
    - Pilot station now on Hönggeberg campus; New building will open in 2020 (at centrum campus)
        - Maker Space – for prototyping
        - Event Space – for communication
        - Idea Space – for developing ideas
    - Extra-curricular offerings
- Pioneer Fellowship: 150 000 CHF over 18 months for start-ups
- Spinoffs: About 20—30 per year

2.11 Strategic Initiatives

- Strategic themes: Medicine, Data, Sustainability, Manufacturing Technology
- Digitalisation: Strengthening of computer science in *all* study programs

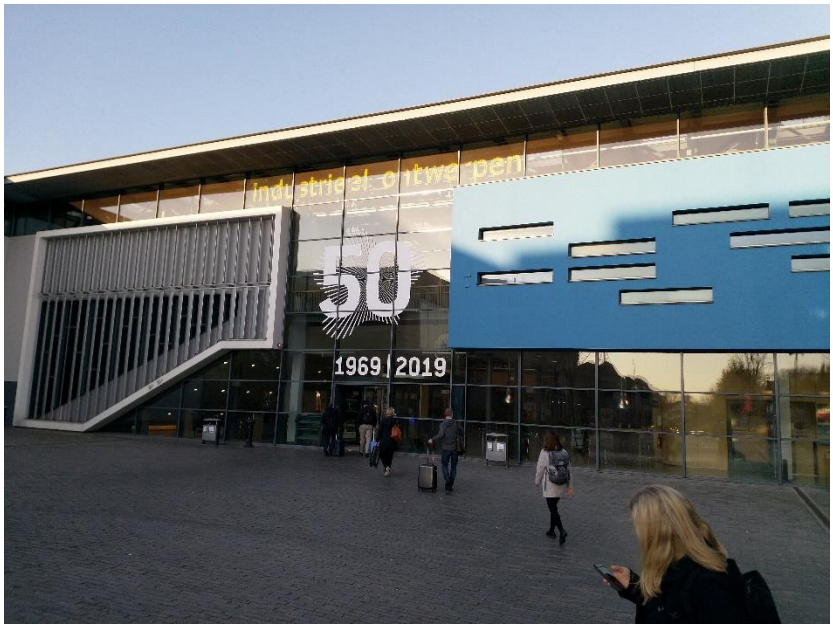
2.12 Faculty training

- "Refresh Teaching": Practice-oriented events at lunchtime for faculty by faculty
- Learning and Teaching Fair: 2-day teaching retreat with all departments

2.13 Other

- Quality assurance:
    - Not all courses are evaluated every time. Alternate years evaluation of courses or exams.
    - Surveys among all students per course – about 60% respond
    - Each department has an education developer (30% central financing)
- Course size: 2—10 ECTS
- Study programs are evaluated in several ways – involving departments, teachers, alumni, students -- and using rating conferences
- Development: Central unit for QA and pedagogical development (LET); about 40 people; all have didactical standing

3 TU Delft



3.1 Key info

University	TU Delft Delft University of Technology
Location	Delft, The Netherlands (one campus)
Type of university	Polytechnical university incl architecture. Public.
Number of (engineering) students	Bachelor: 13 000 Master: 12 000 Ph.d.: 2 800 *Total: 27 800*
Personnell	Scientific: 2 700 Technical/administrative: 1 900 *Total: 4 600*
Number of engineering programs	Bachelor: 16 Master: 33
Website	https://www.tudelft.nl/en/

3.2 Student Recruitment

- Admission requirement (bachelor): Math and physics from high school

- Student population: Large increase last few years, especially in computer science. Scaling up is a general challenge.
- Tuition: For non-Europeans: 15 000 EUR per year; 19 000 EUR for master. For Europeans: 2 000 EUR.
- Dropout: Strong national focus on this issue. Relatively high ph.d. dropout.

3.3 Program Structure

- Used to have 5-year Diploma program before Bologna – now 3-year bachelor and 2-year master
- Increased emphasis on 'soft skills' (ethics; communication; social responsibility) – integrated in regular classes

3.4 Teaching

- Based on CDIO principles
- Methods: Blended learning (online + campus) is used more and more
- Teaching Lab: New building on campus for teacher meetings and training. Very visible.
- Online: MOOCs are free and must be used in teachers' own campus-based classes

3.5 Assessment

3.6 Internships, Relevance

- Large variations between programs
- At Aerospace program, internships are mandatory
    - 12 weeks
    - Typically 3rd year fall semester
    - 18 ECTS
    - 350 students per year
    - 80% go abroad
    - 800 partner companies worldwide

3.7 Non-Technological Skills

- Stronger emphasis on ethics is needed

3.8 Learning Environment

- Language: Dutch in bachelor programs (15 out of 16); English in master programs

3.9 Lifelong Learning

- Online classes are a key factor here
- TU Delft is an active Edx member

3.10 Entrepreneurship

3.11 Strategic Initiatives

- MOOC 2.0:

    - Big growth over 5 years – more than 90 MOOCS and over 3 million students
    - Three aims – reputation building; education/faculty development; reuse in own programs
    - Selected themes – focused portfolio. Portfolio themes:
        - Aerospace Engineering
        - Affordable and Clean Energy
        - Responsible Leadership of Technology
        - Data Analysis and Programming
        - Design and Architecture
        - Medical and Environmental Technologies
        - Industry, Innovation and Infrastructure
        - Fundamental Science
        - Sustainable Cities
    - Products/formats:
        - Open courseware – free, for all, no certificate
        - MOOC – free, for enrolled students, certificate
        - ProfEds – paid, for enrolled students, certificate
        - Online Academic Courses – paid, for enrolled student, full master degree
    - Trends:
        - From distance learning to high-quality learning experiences
        - From courses to programs to credits
        - From national to global world of education
        - From initial education to continuous education
        - Towards open education
    - Material is free; services are not
    - Virtual exchange: Learn online at host institution (e.g. TU Delft); get credits at home university (e.g. MIT Boston)
- High-level "goals":
    - Impact on campus education
    - Financial sustainability
    - Data-driven and evidence-based development
- Math for engineering students (PRIME project)
- Centre for Education and Learning (with Leiden and Rotterdam)
    - Teaching academy: Community of teachers and teaching staff
    - Teaching Lab: New building where teachers can try, discuss and learn teaching
- Role-oriented program design
    - Identified roles: Reseach Specialist; Systems Integrator; Front-end Innovator; Contextual Engineer
    - Aerospace engineering are implementing it; other programs to follow
- Master 2.0 Framework – give students bigger freedom of choice

3.12 Faculty training

- 100 hours compulsory; then optional
- English proficiency test
- Awards for innovative teaching

3.13 Other

- Only 10% of ph.d. graduates continue in academia
- Normal course size is 5 ECTS but there are variations

- Typical bachelor load is 3 courses per semester
- Alumni survey every six years (main takeaway: learned most from master theses, internships, projects)

4 DTU

4.1 Key info

University	DTU – Technical University of Denmark
Location	Copenhagen/Lyngby, Denmark Main campus in Lyngby. Smaller campuses in Ballerup and Risø outside Copenhagen.
Type of university	Technical university
Number of (engineering) students (2018)	BEng: 4200 BSc Eng: 3300 MSc Eng: 4000 Total: 11500
Personnell	
Number of engineering programs	18 Bachelor of Engineering programs 20 Bachelor of Science in Engineering programs 31 master programs
Website	https://www.dtu.dk/english

4.2 Student Recruitment

- Appr 2500 students are enrolled in bachelor programs per year
  - About 150 students in the new international general engineering program
- DTU has doubled its “production” but Denmark still lacks engineers

- Demographics show that there will be fewer youths in Denmark in the future. The solution for DTU is not to lure students from other education areas but to recruit international students and motivate them to stay and work in Denmark
- No tuition fee for EU students

4.3 Program Structure

- Before Bologna: 5-year master programs. Now: 3+2, which DTU is happy with – gives increased student mobility. Wouldn't dream of going back.
- Two types of bachelor programs:
    - 3 years: Preparation for 2-year master programs (97% continue to master)
    - 3,5 years: Profession-oriented; preparation for employment
- Bachelor programs are taught in Danish, with exception of a new program in General Engineering, which is taught in English
- Master programs are taught in English
- Government wants fewer study programs
- DTU's policy is to have:
    - Few and broad bachelor programs
    - Many and narrow master programs
- Program design is built on DTU's so-called flag model, with the flag consisting of four course categories:
    - Competence
    - Technological specialization
    - Electives (many students choose technological courses here)
    - Project

  Categories are equally sized (30 ECTS for master programs)
- Under the optional category, student may choose from > 1600 courses
- The optional category enables international exchange
- DTU give students relatively high flexibility (and responsibility) in composing their education. Students choose wisely because they know they need to be employable at the end.
- Students should be selecting competencies, not courses!
- DTU has a digital planning tool for students, indicating whether the student's course plan fulfills a pre-defined program track or not

4.4 Teaching

- Wide array of teaching methods – flipped classroom, short lectures, problem-based learning in small teams, online courses
- Big lectures are only a small fraction of DTU's teaching
- Important drivers for pedagogical development include lifelong learning and online education
- Diversity is encouraged

4.5 Assessment

- Smaller tests during semesters rather than one big exam at the end
- Many tests and exams are digital
- Wide range of assessment methods – because students learn differently
- New: Peer grading (for interim tests, not final exams)
- New:
    - Upon enrollment, students are taught DTU's honor code system and sign a contract

- Clear sanctions for cheating
- So far, little cheating has been discovered – mostly plagiarism
- New system is well liked among students
- System resembles the context at a workplace

4.6 Internships, Relevance

- No internships in the 3 + 2 programs. Industry are more focused on students having in-depth disciplinary skills. Bachelor programs have an Innovation Pilot course (10 ECTS), where industry present problems and students solve them. Better than internships, since industry does the education, not DTU.
- Internships are part of the 3,5 year profession-oriented bachelor programs. Internships are compulsory and last 6 months.

4.7 Non-Technological Skills

- Math and computer science courses were revised 5—7 years ago as the departments were merged, but the courses are still taught separately
- Ethics is taught as an element in courses on bachelor level. The courses are poorly integrated in the programs, and are not very popular among students.

4.8 Learning Environment

- Dropout rate bachelor level: 35%
  - The big challenge is mathematics. Students who pass math, are almost certain to complete their study.
  - The math course is modular, resource-rich, and well-liked despite high fail rate
- Dropout rate master level: 4%
- No official welcome program for new students enrolled at master level, but student organizations arrange an introdoctury week just before the semester starts. However, it is probably not inclusive enough (one third do not attend)
- DTU is now trying a welcome program that lasts throughout the first semester

4.9 Lifelong Learning

- A long-term goal for DTU: Need to turn education into something people do in parallell with their career -- not before their career

4.10 Entrepreneurship

4.11 Strategic Initiatives

- Evening classes: Instead of new buildings, DTU are aiming for better utilization of existing infrastructure by opening up for evening classes, lab work and other learning activities. Teaching used to take place 8 a.m. -- 5 p.m. but now an evening slot at 6 p.m.—10 p.m. has been opened.
- Biology mandatory: All bachelor students must take at least 5 ECTS of biology (in addition to mathematics/statistics, physics, chemistry, computer science). Engineering is changing – “biology is the new electricity”.
- Entrepreneaurial thesis: All students may write an entrepreneaurial thesis instead of a traditional, research-oriented thesis. The entrepreneurial thesis is a business plan. Students receive an innovation certificate.

- Sustainability: All DTU programs shall integrate sustainability. Now, the focus is on specifying sustainability competences in program descriptions. Next will be how to integrate sustainability into existing courses, and how to evaluate students on this. Green-washing must be avoided – sustainability must be soundly integrated in the programs.

4.12 Faculty Training

- Learning seminar twice a year
- All scientific staff must take pedagogical training (over 2 years)

4.13 Other

- Vision: Technology for humans
- DTU and Denmark play a bigger part on the world scene than their size would suggest – why is this? Denmark doesn't score high on STEM tests in elementary school and high school. However, Danish culture emphasizes collaboration, responsibility and respect and Danish children are taught this from kindergarten on. International students are not used to this. This collaboration culture gives Denmark and Danes a competitive edge.
- DTU and NTNU are in some joint programs, based on the Nordic Five Tech platform. The programs have high student satisfaction scores. The two universities' presidents would like to see much more student exchange between DTU and NTNU.
- DTU decides itself the number of students per program. Government financing is relatively loosely coupled to candidate production.
- QA:
    - Each department has a study board, where half of the members are students
    - Course evaluations by students: Query form with 8 standard questions and also free-form input
- Honour's plan: All master programs have an honours' plan, where students are assigned a mentor who helps them design their study plan. About 5% of the students do this.
- Multi-campus: A challenge, not only practically, but also culturally. How do you merge research-oriented communities with teaching-oriented ones? How do you design career paths for teaching-oriented staff?
- Internationalization: About 40% av master graduates have spent more than 6 months abroad. DTU wants to increase this number.

5 Chalmers

5.1 Key info

University	Chalmers University of Technology
Location	Gothenburg, Sweden. Two main campuses
Type of university	Technical university
Number of (engineering) students (2018)	10 300 (full time)
Personnell	3 100 (total)
Number of engineering programs	Bachelor level: 28 Master level: 41 (Special: 5)
Website	https://www.chalmers.se/en

5.2 Student Recruitment

- Appr 2100 students are enrolled in bachelor level programs per year; appr 1700 in master level programs
- Appr 30% international students at master programs

5.3 Program Structure

- "Civilingeniør" programs are integrated 5-year master programs
    - After three years (bachelor part), students can continue on a 2-year master program of their choice (some of which they have a guaranteed spot at)

    - Bachelor students are guaranteed master programs spots on certain master programs and are qualified/accredited for others
- Bachelor level programs 'Högskoleingenjör' and 'Sjöfartsingenjör' contain more lab and practical work
- Bachelor part (first three years) is taught in Swedish; master part is taught in English
- Master thesis is most commonly done outside Chalmers
- Special programme: "Teacher and 'civilingenjør' "
- Not all "civilingenjör" programs include chemistry courses
- Course size: 7.5 ECTS
- 4 semesters per year – 2 courses per semester (15 ECTS)

5.4 Teaching

5.5 Assessment

- Digital exams in 60 classes (out of 1300 classes in total)

5.6 Internships, Relevance

- Most internships take place in the summer
- Most internships are taken on campus – industry provide tasks and problems

5.7 Non-Technological Skills

- Students need better reflection skills
- Ethics is part of national requirements
- In general, these skills are taught not as separate classes but in an integrated manner
- Important to learn mathemathical way of thinking in order to do modeling and simulation
- All students must have basic ICT knowledge (programming etc) but also need to understand how digitalization influence society and work roles

5.8 Learning Environment

5.9 Lifelong Learning

5.10 Entrepreneurship

5.11 Strategic Initiatives

- Better internationalization of bachelor part:
    - 5th semester taught in English to facilitate student exchange
    - Thinking about teaching 3rd year in English
- One micro master – 'Autonomous driving'
- Global,cooperative student projects:
    - For five years now
    - Last semester in 3rd year
    - Project groups with students from Chalmers and North American partner universities work on challenges given from global companies
    - No travelling – meetings per skype
    - 160 students –half of them from Chalmers
- TRACKS – a 10 year project. Goals and solutions:

    - Education with more cross-disciplinary knowledge
        - Challenge-based TRACKS-classes for students from various programs where they design and build products
    - Individualization of studies
        - Each student creates her profile by electing one or more TRACKS courses
        - Student assesses herself whether preconditions are met or not
    - Shorter lead time for education change
        - Programs are offered in a 'sandbox' format, i.e. a robust frame with flexible, challenge-driven content (e.g. AI, Industry 4.0)
- CHAIR – about AI, 10 years

5.12 Faculty training

- All faculty must pedagogy (15 ECTS) to get permanent employment
- Strategic challenge!

5.13 Other

- Organization structure:
    - A "client/vendor" model: Programmes belong to the vendor part with five education areas, and the courses belong to the client part of the organization (with 13 departments)
    - Programme managers have their own budget, from which they can "shop" courses for their programme. This is to ensure focus on student learning, not professor teaching.
    - Programme managers hold 30% positions
- National frameworks (framing plans) for engineering programs (both bachelor and master level)
- Today's students are pragmatic and goal-oriented – Chalmers need to be more flexible and agile
- In general, very little knowledge about the students on an individual level. Student systems and routines could and should be much more personalized – like social media.

Appendices

A. Program for ETH visit
B. Program for TUD visit
C. Program for DTU visit
D. Program for Chalmers visit