1/1/2019

Periodic evaluation report for MTMT and MSMT

Summary

This report is developed for the evaluation of the two master programs within Materials Science and Engineering at NTNU, MTMT and MSMT. Both are connected to the Faculty of Natural Sciences and the Department of Materials Science and Engineering. A mandate was given for the evaluation and is used as the basis for this report. Three different topics have been highlighted, from this mandate: the study program, program design, and the social and working life relevance. The report shows the status of the study program today and how it has developed since the last in-depth evaluation. Based on a workshop in December 2019 with the evaluation committee, including student representatives and external academic and industrial members, short- and long-term plans for improving the study program have been suggested.

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1. Background and mandate

This report is a part of the periodic evaluation of all the study programs that takes place every 5 years as a part of the educational quality assurance system at NTNU. The last evaluation took place in 2014 in connection with a larger restructuring of the study program known as "fremtidens materialteknologistudieprogram" or “Materials Science and Engineering study program in the future” and involved a wide number of interested parties. In this report it is called the “new” study program.

For this evaluation, the following mandate has been provided and approved by the Faculty of Natural Sciences:

The study program:

- How is the study program linked to the strategies of NTNU and the Faculty?
- Does the name of the study program cover the content of the study program? Does it communicate well with the community?
- Especially related to the main profiles (specializations).
- How is the profile of the study program related to other similar studies at NTNU or other institutions in Norway?
- Especially related to MTPUP (produktutvikling og produksjon)[1]
        - Have there been any significant changes in the structure of the study program since the previous periodic evaluation?
        - Comments related to the materials science and engineering study program in the future. Has it worked? Does it make sense?
    - How is the educational competence developed in the academic environment?
- **Program design**
    - Is there appropriate variation and balance in the study program's teaching and assessment forms?
        - Do the subject compositions give good academic progress?
        - How do the common courses work as part of the study program?
- MTMT vs MSMT
- **Social and working life relevance**
    - How relevant is the study program to society's competence needs?
    - To what extent is teaching in the study program linked to relevant issues from working life?

- Does the student see how subjects are interconnected and provide a competence that is complete in the field? How do students perceive subject composition?
- After the students get out in their first job: do they feel that the study program provided them with sufficient competence and experience in relation to the challenges they face?

[1] https://www.ntnu.no/studier/mtprod

Committee

Ida Westermann – Head of the committee and leader of study track “Materials development- and use”

Ragnhild Aune - Former Academic Programme Director (MTMT)

Frode Seland – Academic Programme Director (MTMT/MSMT)

Roald Lilletvedt – Academic Programme Director (FTHINGMAT)

Kari Ravnstad Kjørholt - Student representative

Maren Elise Juul – Administrative coordinator

2. The evaluation work form

The periodic evaluation is carried out in form of a self-evaluation report written by the internal committee. This report describes the study program from before the 2014 evaluation, the changes implemented after the 2014 evaluation, and how it has developed further in recent years. It also includes two surveys. One student survey was sent to current students, and one was sent to alumni who have graduated within the last 5 years. The latter survey gives valuable information about the societal and industrial needs and the competence that the students feel they possess after 5 years of study.

The self-evaluation report has been sent to an evaluation board consisting of external representatives from industry (3), international academia (2), students (1) and representatives from another faculties at NTNU (2). Finally, the committee and the board met for a one-day seminar to discuss the present study program and to come up with short and long actions to improve the study program.

3. SWOT

The following SWOT of the materials science and engineering program was submitted to the faculty as a part of the yearly educational quality assurance system in 2018.

Strengths	Weaknesses
• Good contact with Norwegian industry provides research-based teaching. Several adjunct professors recruited from the industry. • Good contact between students and academics / research groups. Good follow-up of the individual student. • Excellent study environment where students have good contact with each other. • Good combination of theory and experimental work. • Former students give feedback that the study is useful and relevant to working life.	• High dropout rate. • Relatively few students (small program) mean that some subjects can quickly become subcritical. • Weak in some fields such as welding and polymers. • Inadequate routine for reviewing that the content of topics is adapted to the orders of the program councils. • Few direct exchange agreements.
Opportunities	**Threats**
• Opportunities for even better cooperation with Norwegian industry in certain subjects and disciplines. • Opportunity for a more holistic focus on research-based innovation, innovation, digitalisation and sustainability in education • Periodic evaluation provides opportunities to ensure and develop good learning strings in the study program through the development of the course portfolio. • Scientific integration. Making teaching in a new department structure more efficient.	• Low financial count and merit for teaching. • High staff and equipment costs associated with laboratory training. • Limited capacity for technical assistance and training related to laboratory work and teaching in several subjects may affect the laboratory access. • Industrial cooperation around bachelor's and master's theses may conflict with international cooperation and IPR.

4. Materials science and engineering as part of NTNU's strategy

Material Science is an applied science concerned with the relationship between the processing, structure and properties of materials. The program offered at NTNU involves the characterization of the physical and chemical properties of materials covering metals/alloys, ceramics, magnetic materials, optical materials, semiconductors, superconductors, and composites, as well as the manufacturing processes. The program comprises the study of materials all the way from the atomic scale to the macro scale, and it is fundamentally concerned with the effect of processing methods, as well as structure and chemistry, on the properties of materials. The program also includes the use of these engineering materials in different environments, as well as in different applications and areas of the society. The main focus of the program is on teaching the students to use their knowledge to synthesize new materials with special properties, as well as to characterize, evaluate and improve existing materials characteristics.

Knowledge about materials and materials science is of paramount importance in industry and society, where production of all physical objects involves materials. Materials are therefore a necessity in almost all industrial enterprises and represent an important focus area in the whole industrialized world. The labour market for candidates with materials science background is in general very good. The graduates from the program are highly sought-after and are usually employed in industry, research laboratories or academia where they develop products and product-related technologies.

NTNU is committed to providing the highest quality education in Materials Science and Engineering (MSE), conducting world-class basic and applied research, addressing the evolving needs of industry and society, and supporting the further development and competitiveness of Norway industry.

The overall strategy for NTNU is "Knowledge for a better world", with four strategic research areas being identified and established; Energy, Health, Oceans and Sustainability. The strategy puts clear emphasis on the United Nation´s 17 Sustainable Development Goals. Furthermore, internationalization of the education and research activities, i.e. the development of research and educational collaborations with other international communities remain important.

The Faculty of Natural Sciences has adopted NTNUs strategy and narrowing its main focus in the current period to four key strategic areas, i) Sustainability, ii) Relevance for working life, iii) Innovation, and iv) Digitalization. These areas should then be reflected in all parts of the organization, including the study programs. This is to ensure that the integrity of the learning outcomes in the study program matches the learning outcomes of the individual courses and vice versa. In other words, the overarching, as well as the detailed learning outcomes of the study program should be reflected in the courses that the program is comprised of.

The following describes briefly how the four strategic areas are implemented in study program today and in what courses:

i) Sustainability

United Nations has put forth 16 sustainability goals, where the Faculty of Natural Sciences explicitly mention 9 of these as strategic focus areas for the faculty and its activities. These areas should be strengthened by offering relevant education, develop research-based knowledge and through sustainable administration of natural resources and technological value creation.

Production processes, independent of material type, are energy consuming. The need for materials, now and in the future, will proceed. The challenges are to make the manufacturing process and use as energy cost effective and environmentally friendly as possible. In addition, recent environmental and societal events have emphasized the need to focus on green energy and sustainability for improved realization of graduated candidates. Furthermore, we expect a decline in the oil and gas sector in a future sustainable society, calling for necessary changes in the study programs. The study program is considered robust with respect to subject portfolio, but the focus should be shifted more towards sustainability. Currently, the study program answers directly in particular to the UN goals 7: Affordable and clean energy, 12: Responsible consumption and production and 4: Quality education. Courses where larger parts of the curriculum are relevant for sustainability are (see detailed study plan for when they are offered):

TMT4340 Materials and sustainable development

TMT4345 Material development

TMT4306 Metal production – ferroalloys, iron and steel

TMT4326 Refining and recycling of metals

TMT4285 Hydrogen technology, fuel cells, batteries and solar cells

TMT4330 Resources, energy and environment

TMT4322 Solar cells and photovoltaic nanostructures

TEP4285 Material Flow Analysis (K-emne)

TMR4137 Sustainable Utilization of Marine Resources (K-emne)

ii) Relevance for working life

The study programs in materials science are closely intertwined with industrial interests and are conceived as possessing high relevance for working life. This is supported by annual student surveys.

This topic is described in more detail in section 8.

iii) Innovation

Innovation and entrepreneurship are pervasive topics in the study program, although not being the main topic in any specific courses. In addition to the compulsory course TIØ4258 Technology Management students have the option of choosing complementary courses ("K-emner") that highlights entrepreneurship in more detail. From a materials science and engineering point of view, all program specific courses are founded on historic discoveries and academic progress that have become established knowledge. All courses at NTNU should have research-based lecturing. This is secured through faculty members performing active research commonly related to topics in the courses they are teaching. Below is a list of courses, offered in the program, with parts of the course containing education on innovation.

TIØ4258 Technology Management

TPD4142 Design Thinking (K-emne)

TPK4141 Innovation, Design and Production 1 (K-emne)

TMM4220 Innovation by Design Thinking (K-emne)

TSOL425 Technology Management in Teams (K-emne)

iv) Digitalization

The Faculty of Natural Sciences has an ambition that graduated candidates shall possess digital competence and skills satisfying future societal and industrial needs. Four categories of digitalization are identified; 1) use of digital tools (e.g. simple work sheets), 2) digital tools for use in teaching and evaluation (e.g. digital exam using Inspera (exam software)), 3) digital tools for interaction and communication (e.g. Blackboard and Sharepoint) and 4) competence in software relevant for the discipline of study (e.g. HSC Chemistry).

In the following table, a coarse overview of digital competence offered in various courses in the MTMT program is provided.

Table Digital competence targets and links to courses in the MTMT program

Basic ICT competence	Yes	TDT4110, TMT4110, TMT4171, TMT4240, TMT4210
Handling large data set	Yes	Project and master thesis work (TMT4500, TMT4905)
Statistical methods	Yes	TMA4240, TMT4210, TMT4166, TMT4260, TKJ4205, TMT4500, TMT4905
Programming skills	Yes	TDT4110, TMT4260, TDT4110, TKJ4205, TMT4500, TMT4905, TMM4155
Basic data security	No	Perhaps in Experts in Team
Use of specific academic programs/tools	Yes	Python (Anaconda), HSC Chemistry, Avogadro, Excel, word, etc. [1]
Algorithmic understanding	Yes	TMT4166, TDT4110, TMT4260, TMT42210, TKJ4205
Modelling and simulation	Yes	TDT4110, TMT4260, TMT4210, TKJ4205
Robotization, ICT architecture	No	
Statistical research planning and statistical analysis	No	Exists in some complementary courses
Numerics and numeric solution of sets of equations	Yes	TMT4210, TMT4260, TMT4905, TMT4500

[1] This is a simplified list of software in use. Software like Origin, Sigmaplot, Comsol, etc. are used in various project and master thesis work, but not listed explicitly here.

5. The structure of the study program

The 5-year master's program in Materialteknologi (MTMT, Materials Science and Engineering) and the 2-year international master's program in Materials Science and Engineering (MSMT) are professional education programs focused on materials. Both programs give our graduated students the title “Sivilingeniør”. General requirements for admission and content to the “Sivilingeniør” degree programs are determined by the Management Committee for the “sivilingeniør” degree programs (FUS) and include requirements for mathematics, statistics, physics and complementary subjects (see study plan). The study also provides in-depth knowledge of one of the main profiles (specializations) offered by the study programs.

The technology / “sivilingeniør” program is a brand that has been built up over many years, and which in itself says something about what the program generally provides in terms of qualifications for applicants to the program, students, graduated candidates and employers. The Master's programs in Materials Science and Engineering are interdisciplinary study programs, offered in collaboration between the NV (Natural Sciences) and IV (Engineering) faculties. The Natural Science faculty is the host faculty for the MTMT/MSMT programs and program specific courses are by large supplied by two departments; NV-IMA Department of Materials Science and Engineering and IV-MTP Department of Mechanical and Industrial Engineering. The foundation and main bulk of courses, however, lies with the Department of Materials Science and Engineering. The overview of the two study programs are briefly outlined below. More details on elective courses, including experts in team (EIT) villages, are provided in separate documents.

All courses in both programs are research-based and are developed through a strong connection between academia, research institutions, industry and commerce resulting from broad academic networks established by the scientific staff. Important aspects of program development arise also from cooperation between stakeholders in several research and educational projects, guest lectures and joint supervision of project and master students.

5.1 The 5-year integrated MTMT study program

The MTMT program has a total of 300 credits spread over 10 semesters (5 years). The **first two years** of study are common to all students in the program. These 2 years include 120 credits divided into 16 courses of 7.5 ECTS in materials science and thermodynamics (7 subjects), mathematics (4 subjects), physics (1 subject), information technology (1 subject), chemistry (2 subjects) and the NTNU common subjects ex .phil. (see also general study plan in the table below and complete study plans online). Knowledge about national industry is provided through a 1-week excursion in the introduction course to materials science (TMT4171 Introduction to Materials Science) along with monthly seminars from alumni that are currently working in Norwegian industry.

In year three, all students have statistics (1 course) and one technology management course. From year three, the students must choose one of three main profiles (choice towards the end of 4th semester):

1. “resources, energy and environment”
2. “materials development and use”
3. “materials for energy technology”

In the final two years (master part of the degree), all "sivilingeniør" programs (5-year integrated study programs) have 2 complementary courses ("K-emner"), one course from another engineering study program (“ING-emne") and the NTNU-specific course "Experts in Team" (EIT). In EIT, the students have a broad selection of topics to choose from. All programs also have a 15 credits specialization project in the 9th term and a 20 weeks master thesis work in the final 10th term. The topic of the work must be relevant for the chosen specialization. It was suggested that ex.phil. could be moved to the fourth semester, spring second year. This was suggested based on i) the heavy work load that students experience in the fourth term stemming from laboratory modules in three of the courses with affiliated reporting, and ii) making room for an additional scientific course in the first semester. An alternative is to move inorganic chemistry to 2nd semester and chemistry to 1st semester. This will be further discussed in the study program board.

5S	Master Thesis (in a topic relevant for the chosen specialization)				SPECIALIZATION
5F	Complementary course (not technical)	Elective course (from list - specialization)	Specialization project (in a topic relevant for the chosen specialization)		
4S	Experts in Team	ING course (from list – course from another engineering program)	Elective course (from list - specialization)	Elective course (from list - specialization)	
4F	Complementary course (not technical)	Elective course (from list - specialization)	Elective course (from list - specialization)	Elective course (from list - specialization)	
3S	TIØ4258 Technology Management	TMT4252 Electrochemistry	TMT4301 Materials Characterization	Elective course (from list - specialization)	
3F	TMA4240 Statistics	Conditional compulsory course (specialization)	Elective course (from list - specialization)	Elective course (from list - specialization)	
2S	TMT4125 Calculus 4N	TKP4100 Fluid flow & Heat Transfer (Intro. Course)	TMT4130 Inorganic Chemistry	TMT4276 Basic Thermodynamics	COMMON
2F	TFY4104 Physics	TMA4110 Calculus 3	TMT4345 Materials Processing	TMT4340 Materials & Sustainable Development	
1S	TKT4126 Mechanics	TMA4105 Calculus 2	TMT4110 General Chemistry	TMT4178 Applied Materials Technology	
1F	EXPH0300 Exam philosophicum	TMA4100 Calculus 1	TDT4110 Information Technology (Intro. Course)	TMT4171 Introduction to Materials Science	

Colour codes:

Not technical courses (compulsory/elective), Basic courses (compulsory), MSE courses (compulsory), Elective courses, Technical course

Figure 1. Overview of the study plan for the 5-year MTMT program as of 2018/2019. Colour codes are indicated below the table. See more details in a separate excel sheet, which includes links to all courses offered in the program.

5.1.1 Learning outcome MTMT program

The learning outcomes for the study programs reflect the content of the courses offered in the study program.

It is imperative that the learning outcome and ambitions in the study program equip our graduate students with necessary skills to solve tomorrow's challenges, including providing them with a sustainable mindset and awareness for a better future world. It is suggested that the study program implements a systematic approach to rigorously incorporate UN's sustainability goals, which should build on a common platform for all technology programs put forth by FUS or the rectorate in accordance to current strategies. K-5 explicitly includes "sustainability". S5 and S6 also includes "sustainable". The following learning outcomes are valid.

<u>Knowledge</u>

K-1 Be able to evaluate how microstructure and functionality of materials (metals, ceramics, composites, plastics and/or simple functional materials) are controlled by the chemical composition, and how the materials are produced and processed.

K-2 Have a wide and essential knowledge foundation within materials science, materials characterization (with laboratory experience), materials properties, sustainable material production and electrochemistry, as well as basic knowledge within transport phenomena, fluid dynamics, heat convection, mechanics and sustainability analysis of materials.

K-3 Have basic theoretical and practical knowledge within important characterization techniques for materials; light microscopy, electron microscopy, x-ray diffraction, in addition to mechanical and chemical properties

K-4 Have considerable basic knowledge within mathematical and natural science subjects such as mathematics, physics, chemistry, thermodynamics and statistics, as well as computer science, all of which forms a common platform for the technological and advanced subjects in the study program.

K-5 Have basic knowledge within technological leadership, entrepreneurship, innovation processes, digitalization, economics, as well as sound knowledge within health, safety, sustainability and environment.

K-6 Have advanced knowledge and sufficient scientific insight to make use of new scientific research results within one of the three specializations (study tracks) in the study program; i) Resources, Energy and Environment, ii) Materials Development and Use, or iii) Materials for Energy Technology.

Resources, Energy and Environment

K-HP1 -1 Have detailed knowledge of the manufacturing and refining processes with main focus on processes in the metal industry (ferroalloys- and light metal industry) including carbothermic, electrolysis and refining processes

K-HP1-2 Have in-depth insight and understanding of what determines chemical equilibrium, and how this can be described with Gibbs energy functions and phase diagrams

K-HP1-3 Have advanced knowledge about industrially transport phenomena as well as heat- and mass transport for one phase- and multiphase systems

Materials Development and Use

K-HP2-1 Have comprehensive knowledge about development of advanced materials (composites, nanostructured materials and alloys), material selection and sustainable development, including further development and use of construction materials

K-HP2-2 Have exhaustive insight in the microstructure and chemical composition of materials and their connection to materials properties and production processes, including recycling of materials.

K-HP2-3 Have advanced knowledge within several of the following areas: corrosion, fracture mechanics, metallographic- and electron optical methods, mechanical properties of metals, fatigue, selected functional properties, casting, joining, polymers, tribology, phase transformations, crystallography, crystal plasticity, metalshaping and numerical materials modeling

<u>Materials for Energy Technology</u>

K-HP3-1 Have advanced theoretical and practical knowledge connected to several of the most relevant functional materials that have key roles in energy production, energy conversion and/or energy storage with emphasis on renewable and sustainable energy solutions and related fields, including photovoltaic (solar) cells, fuel cells, water electrolysis, , thermoelectricity and batteries

K-HP3-2 Have advanced knowledge within one or more of the following: i)electrochemical thermodynamics and kinetics, ii) structure and properties (including corrosion) of metals, ceramics and composites, iii) electron structures and functional properties of solids, iv) modern calculation methods for structural modelling and properties

K-HP3-3 Have advanced knowledge of key experimental methods within the chosen specialization

<u>**Skills**</u>

S-1 Can solve advanced material science challenges in industry and research, in an independent and systematic way by analysing issues, formulating sub-tasks and producing innovative and sustainable solutions

S-2 Can analyse and improve material properties and material science processes for production, refining and processing (melt processing, thermal conditions, deformation conditions, surface treatment, welding conditions, etc.)

S-3 Can use and develop alternative and innovative solutions of material-related problems in the selection of materials for specific applications, material treatments and conditions adapted to different application areas.

S-4 Can independently carry out assessments that can shed light on whether proposed technological and economic methods and techniques are socially acceptable and in line with current research ethical and sustainability norms

S-5 Can use advanced scientific equipment for characterization of microstructure and properties of selected materials, depending on main profile and specialization

S-6 Can lead projects and a production unit related to material technology activities (metal production, casting or further processing) in an efficient, economical, sustainable and socially beneficial manner

Resources, Energy and Environment

S-HP1-1 Can calculate energy consumption for the individual processes and evaluate the reduction of energy consumption and methods for energy recovery

S-HP1-2 Can calculate industrial mass and heat flows

S-HP1-3 Can calculate and control the composition of the end products

S-HP1-4 Can evaluate energy and environmental impacts on industrial processes

Material Development and Use

S-HP2-1 Can work with improvement and further development of production processes, either individually or in collaboration with a research group

S-HP2-2 Can select the right types of materials, joining methods and corrosion prevention measures for different usage and operating conditions

S-HP2-3 Can initiate investigations, independently or in collaboration with a research group, to arrive at the right material selection and treatment

Materials for Energy Technology

S-HP3-1 Can select the right types of materials for selected functional materials, and also improvise and further develop and enhance the functionality of some materials used in one or more energy conversion units or other selected processes

S-HP3-2 Can analyze and evaluate the relationship between material quality and performance within the chosen specialization

S-HP3-3 Can characterize materials with functional properties such as electronic and ionic conductivity, insulating, magnetic, catalytic and/or mechanical properties

S-HP3-4 Can perform advanced calculation with related to material design for selected processes

General Competence

G-1 Deliver well-structured presentations for both professionals and non-specialists with and without modern presentation tools

G-2 Write well-structured and clear reports and contributions to scientific publications

G-3 Communicate the requested knowledge and results in a clear and convincing manner

G-4 Be able to read, interpret and summarize English-speaking technical literature in writing and orally

G-5 Assess and predict technological, ethical and social effects of one's own work and take responsibility for the effect of the work on sustainable and social development

G-6 Conduct risk assessments and know safety instructions for own work

G-7 Can follow the main lines of the knowledge development within personal field of expertise to ensure academic updating

G-8 Have good contact with experts in the field and be able to establish international professional networks

G-9 Can work independently and in interdisciplinary groups and collaborate efficiently with specialists and take their own initiatives

5.1.2 Learning outcome matrix with courses (bulk courses)

Studieprogrammets læringsutbytter (K=Kunnskap, F=Ferdighet, G=Generell kompetanse)	Exphil	Basisemner (Kjemi, Matte, Fysikk, IKT, Termodyn.	Teknologiledelse, HMS, Eksperter i Team	Grunnleggende materialteknologie mner	Fordypningsemner i materialteknologi	Ingeniøremne annet studieprogram	Komplementærem ner	Prosjekt- og masteroppgave
K-1				x	x			
K-2				x				
K-3				x				
K-4		x						
K-5		x	x				x	
K-6					x	x		x
K-HP1-1					x			x
K-HP1-2					x			x
K-Hp1-3					x			x
K-HP2-1					x			x
K-HP2-2					x			x
K-HP2-3					x			x
K-HP3-1					x			x
K-HP3-2					x			x
K-HP3-3					x			x
F-1				x	x			x
F-2		x		x	x	x		x
F-3				x	x			
F-4			x					x
F-5				x	x			x
F-6			x				x	
F-HP1-1			x		x			x
F-HP1-2					x			x
F-HP1-3					x			x
F-HP1-4					x			x
F-HP2-1					x			x
F-HP2-2					x			x
F-HP2-3					x			x
F-HP3-1					x			x
F-HP3-2					x			x
F-HP3-3					x			x
F-HP3-4					x			x
G-1	x		x	x	x		x	x
G-2			x		x			x
G-3			x	x	x	x		x
G-4			x	x	x	x		x
G-5	x		x	x			x	
G-6			x					x
G-7	x		x		x			x
G-8								x
G-9			x					

Figure 2 Table with learning outcomes and links to courses in the program

5.2 The 2-year international MSMT master study program

The 2-year international master study program MSMT (Master in Materials Science and Engineering) has a total of 120 credits (ECTS) distributed evenly over 4 terms (2 years). There are two mandatory common courses in the first term (TMT4155 Heterogeneous Equilibria and Phase Diagrams and TDT4127 Programming and Numerics[2]) and one mandatory course in the second term (TMT4301 Materials characterization). All students must also do the Experts in Team course, a signature course for the technology programs at NTNU, in the second term and one complementary course (K-emne) in the third term. See the study plan in separate excel document with links to the various elective courses.

Students in the international 2-year master program are accepted directly into one of the study specializations, which have the same names as the five years integrated study program (MTMT):

[2] This course was taken into the study program in the fall of 2019 as a requirement for all "sivilingeniør" candidates to have sufficient programming experience.

1. "ressurser, energi og miljø", (Resources, Energy and Environment)
2. "materialutvikling og -bruk", (Material Development and Use)
3. "materialer for energiteknologi", (Materials for Energy Technology)

The study program has significant laboratory and project work in connection to the courses, which is natural for this kind of studies. The first year has 60 credits with 8 courses of 7.5 credits each. The third term consists of one specialization course related to the project work, one complementary course (K-emne) and a 15 credits project work, usually of experimental character. Similarly, to the MTMT program, the fourth and final term is the master project work (30 credits, 20 weeks). Internal surveys have shown that students spend significant time on the 15 credits project work and the 30 credits master thesis project, commonly more than the stipulated time.

The study plans for MSMT is provided below. The detailed study plan with links to courses is given in a separate spread sheet (excel). In the separate document, all elective courses are provided as well. VA subjects are elective courses that are considered when planning the overall time schedule and exam in order to avoid teaching and teacher collision. VB subjects are elective courses not being considered in the planning of the overall time schedule.

MSMT and MTMT have a very similar study plan for the last two semesters. It was discussed if there should be fewer elective courses for the MSMT students, especially the first two semesters. This would give a more fixed set of knowledge, depending on the study track, to the MSMT and give a clear difference between the two study programs, including learning outcome. Then it is also possible to offer a mandatory course for the MSMT students to cover missing knowledge from their bachelor's degree.

5.2.1 Study plan for MSMT

<table>
<tr><td>2S</td><td colspan="4">Master Thesis (in a topic relevant for the chosen specialization)</td><td rowspan="4">STUDY PROFILE</td></tr>
<tr><td>2F</td><td>Complementary course (not technical)</td><td>Elective course (from list - specialization)</td><td colspan="2">Specialization project (in a topic relevant for the chosen specialization)</td></tr>
<tr><td>1S</td><td>Experts in Team</td><td>TMT4301 Materials Characterization</td><td>Elective course (from list - specialization)</td><td>Elective course (from list - specialization)</td></tr>
<tr><td>1F</td><td>TMT4155 Heterogeneous Equilibria and Phase Diagrams</td><td>TDT 4127 Programmeing and Numerics</td><td>Elective course (from list - specialization)</td><td>Elective course (from list - specialization)</td></tr>
</table>

In addition: HMS0003 Health, Safety and Environment (HSE) course for master students (compulsory, 0 credits)

Figure 3 Study plan for MSMT program Details on elective courses are provided in a separate spread sheet.

5.2.2 Learning outcome and learning matrix

The learning outcomes of the 2-year master study program are as follow:

General competence:

The Master graduate in Materials Science and Engineering:

G-1 Has an understanding of the role of engineering in a comprehensive societal perspective, has insight into the ethical challenges and considerations concerning sustainable development, has the ability to analyse ethical problems connected to engineering tasks, and contribute to innovation and entrepreneurship opportunities.

G-2 Has the ability to disseminate and communicate engineering problems and/or solutions to specialists and the general public.

G-3 Has the ability to cooperate in an interdisciplinary environment.

G-4 Has the understanding of possibilities and limitations of using information and communication technology, including juridical and societal aspects.

G-5 Is able to lead and motivate co-workers, as well as have an international perspective on their profession, and develop an ability towards international orientation and cooperation.

Knowledge:

The Master graduate in Materials Science and Engineering

K-1 Has a broad knowledge of mathematics, science, technology and computer science, as a basis for understanding methods, applications, professional advancement and adaptations.

K-2 Has broad engineering- and research-based knowledge of materials science and engineering, with in-depth knowledge within a more limited area connected to active research, including sufficient professional insight, making use of new research results.

K-3 Has insight into selected social sciences, humanities and other non-technical disciplines of relevance to the exercise of the engineering profession and, as a basis, develop a broad perspective on the engineering discipline’s role and challenges in the society.

Skills:

The Master graduate in Materials Science and Engineering

S-1 Can define, model and break down complex engineering problems, as well as choose relevant models and methods, and carry out calculations, finding solutions independently and critically.

S-2 Can develop comprehensive solutions to engineering problems, including the ability to develop solutions in an inter-disciplinary context, independently carry out engineering research and development projects, under academic supervision.

S-3 Is able to advance and adapt professionally, and develop professional competence on their own initiative.

The following provides an overview of the learning outcomes and how they link to the various courses offered in the program. A detailed overview for each individual course does not currently exist.

Studieprogrammets læringsutbytter (K=Kunnskap, F=Ferdighet, G=Generell kompetanse)	Inngangskunnskap tilsvarende bachelor. Dvs basisemner i kjemi, fysikk, termodynamikk, IKT	Grunnleggende materialteknologiemner fra bachelor	Komplementæremner og andre inngående ikke-ingeniøremner	HMS, Eksperter i Team	Fordypningsemner i materialteknologi	Ingeniøremne annet studieprogram	Prosjekt- og masteroppgave
K-1	x	x					
K-2		x			x		
K-3		x	x	x			
S-1	x	x		x	x	x	x
S-2		x		x	x	x	x
S-3					x		x
G-1		x	x	x	x		x
G-2				x	x		x
G-3		x	x	x	x	x	x
G-4	x		x	x			x
G-5			x	x	x		x

Figure 4 Table linking learning outcomes to the courses in the study plan.

5.3 Forms of instructions, educational and evaluation methods

In general, each course has four hours lectures, 2 hours exercise (problem solving) class and 6 in-depth study hours every week, including a mandatory laboratory part. The lectures are still mostly traditional (blackboard or powerpoint) lectures, but most courses strive to have student interactive activities. Furthermore, in-line with governmental requirements and expectations, more and more courses include some sort of project work as a compulsory part of the course. This project work is either given a pass/no pass or own evaluation counting towards the final grade. In the more advanced graduate courses, the students will often make use of a combination of more advanced measurement techniques and data treatment, which is important training before proceeding with project and master thesis work. Some courses have also moved from an exclusive final exam mark to a portfolio assessment. In TMT4210 Materials and process modelling, for instance, the students do several small projects that are assessed on the fly. TMT4166 Experimental materials chemistry and electrochemistry has a lecturing part that are tightly tied up to the laboratory part of the courses. Mandatory laboratory reports, including data collection and treatment, are handed in and assessed.

Albeit most courses have a problem solving (exercise) class with mandatory hand-in of 50-80% exercises, and an additional laboratory or project work part, the majority of the courses still have one final examination that counts for 100% of the grade in that course. At the department of materials science and engineering about 75% of all courses have a 100% marks final exam and this is probably close to the current status for the study programs as well. The committee members from the industry expressed that they would like the students to write individual reports. Report writing is an important skill to have as a graduate. It is possible to create several smaller report exercises, to decrease the workload on the students and course coordinator. It is also possible to have partially filled out reports, so the students only need to fill in the missing parts. It is then possible to focus on the learning of specific parts of the reports at a time. With individual report writing it opens for other evaluation methods like portfolio assessment.

In 2018, the faculty of natural sciences required that 50% of all final examinations should be conducted using a digital exam paper with the software Inspera, offering a tailormade solution for NTNU. From, and including 2019, all final examinations must be in the form of digital exams using Inspera. More than 90% of all courses had digital exam in spring 2019 (exceptions are master thesis, experts in team and genuine laboratory courses). The amount of alternative examination tasks, such as multiple choice and pairing questions have apparently increased. No assessment of the change in learning outcome with implementation of digital exam is done, nor planned. Courses with few students and second sitting exams could be made oral instead, and is often the case (less than 5-7 students).

In general, courses at the graduate (master) level have fewer students in each class and are better suited to have strong interaction between students, lecturers, technicians (laboratory engineers), faculty members and guest lecturers.

It is important with good communication between the course coordinators that have the same set of students one semester. It should, for example, be possible to include subjects from mathematics and information technology into the course in materials science and engineering, the first semester. It will take time to work on the communication and this will therefore be a long-term goal.

Students and industry expressed that they want a focus on digitalization. Our graduates should be able to handle big data. This can be solved by offering courses that already exist, as a k-emne or ING-emne. The study program also wishes to create a material related course at master level, that includes more advanced programming.

5.4 Student Workload

The current guidelines for NTNU builds on that one year of study is minimum 1600 hours and normally not more than 1800 hours work load for the students. The student year is fixed to 40 weeks and a fulltime education gives 60 credits (ECTS) per year. Broken down this means that the average work load for students will be (some courses and some study programs may have higher requirements for the students):

- 40 - 42,5 hours per week (average for the study year).
- 26 - 29 hours per credit (average for the study year)
- One week of study is about 1.5 credits
- One course of 7.5 credits corresponds to about 5 weeks of full-time study, which is at NTNU between 195 and 217.5 hours of study.

According to surveys students tend to work more than the recommended 40-42.5 hours per week, reported to be 45.5 hours for MSMT and 43.8 hours for MTMT (numbers are collected from the annual SHOT survey[3])[4].

The students at MTMT have given feedback that the fourth semester, spring second year, has a large workload with significant laboratory activity in two of the four courses.

5.5 Student recruitment

The study programs are the strongest and largest study programs directed at materials and materials science and engineering being offered in Norway.

5.5.1 MTMT

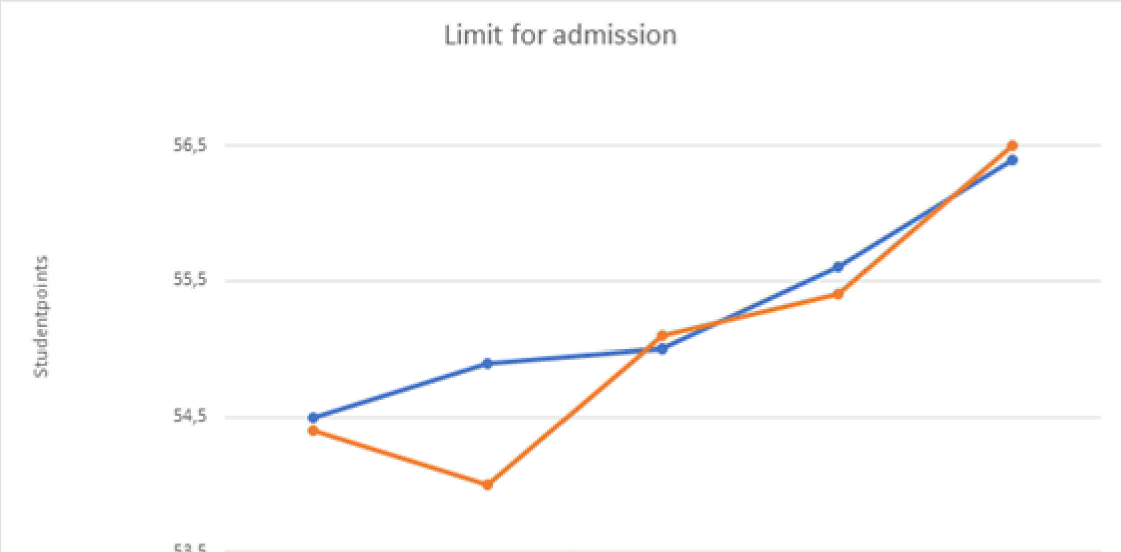
The 5-years integrated master study program recruit the majority of students directly from high schools (videregående) across entire Norway. The language of study in the first two years must be Norwegian or another Scandinavian language. This is a stringent requirement put forth by our owners, the ministry of education and research. Thus, all students that are accepted into the program must also master a Scandinavian language. Consequently, there are limited students from other countries in the MTMT program. In addition, there is a limited number of available spots in the program, which has increased slightly over the last few years due to improved recruitment. In 2018/19 and 2019/20 this was 36 and for 2020/21 it is suggested to be 40[5]. Typically, somewhere between 30-40 students accept and enroll in the first year out of about 55 spots being offered. Figure 5 shows the number of students in the ordinary intake to the MTMT program along with the

[3] https://www.studenthelse.no/

[4] The survey "Studiebarometer 2019» showed 36.3 hours per week, which is significantly lower. This survey was done after our own survey and the results was not published until February 2020, and is therefore not included in this evaluation.

[5] This number is decided by our owners and administered by FUS. In 2019, the total frame for the 5-year integrated "sivilingeniør" master program at the NV faculty was 306 (Physics and mathematics: 115, Chemical engineerirng and biotechnology: 115, Nanotechnology: 36 and Materials Science and Engineering: 36. For 2020 Chemical engineering gives 4 spots to MTMT.

number of first-time applicant and the affiliated grade requirement (student points). The program seems to be more competitive and attracts stronger students.



	2015	2016	2017	2018	2019
Ordinary	54,5	54,9	55	55,6	56,4
First time applier	54,4	54	55,1	55,4	56,5

Figure 5 Development in limit for admission to the MTMT program based on grades from high-school

5.5.2 MSMT

Recruitment to MSMT is split into different geographical regions, but they all require background in materials science in addition to sufficient mathematics and statistics (at least 30 credits), chemical thermodynamics and chemistry to be accepted into the program. Some smaller variations exist between the different specializations.

Currently the 3-year engineering study program in materials technology (materialteknologi, FTHINGMAT[6]) is acknowledged as sufficient background for direct acceptance to the MSMT program. Also, the bachelor mechanical engineering education with materials science direction from University of Stavanger is also approved for direct acceptance, for the specialization “Materials development and use” as well (a chemical thermodynamics or physical chemistry course is required in the study plan)[7]. The similar mechanical engineering study program from Oslo Metropolitan University does not qualify for direct acceptance in MSMT due to lack of chemical thermodynamics, chemistry and/or materials science background.

A wide number of international university educations are approved for acceptance to the MSMT program based on sufficient background. The allocated spots in the program were 18 in 2019/20

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[6] https://www.ntnu.no/studier/fthingmat
[7] https://www.uis.no/studietilbud/ingenioer-og-sivilingenioer/bachelor-i-ingenioerfag/maskin/

and also suggested in 2020/21 (split: 3 Outside EU, 3 within EU and 12 Norwegian/Nordic). The program offers typically 30-40 students a spot in the program. Somewhat 15 students are accepted from Norwegian (or Nordic) universities and university colleges, roughly 1-2 from European institutions and 2-6 from Universities outside of Europe; in general, from all over the world. 13 from Norwegian (or Nordic University) and 5 from non-EU countries have started in the MSMT program the fall of 2019. All of the norwegian students did their bachelor's degree at NTNU (FTHINGMAT).

5.6 Student abandonment

Students that withdraw from the program has been, and still is, a major problem with the materials science and engineering programs, in particular during the first year of the MTMT program. Figure 6 clearly illustrates this problem at the MTMT program. In 2015 and 2016 the majority of reduction in active students (blue) were internal transfers (overgang, yellow), while in 2017 and 2018 the drop-out were around 20% (red).

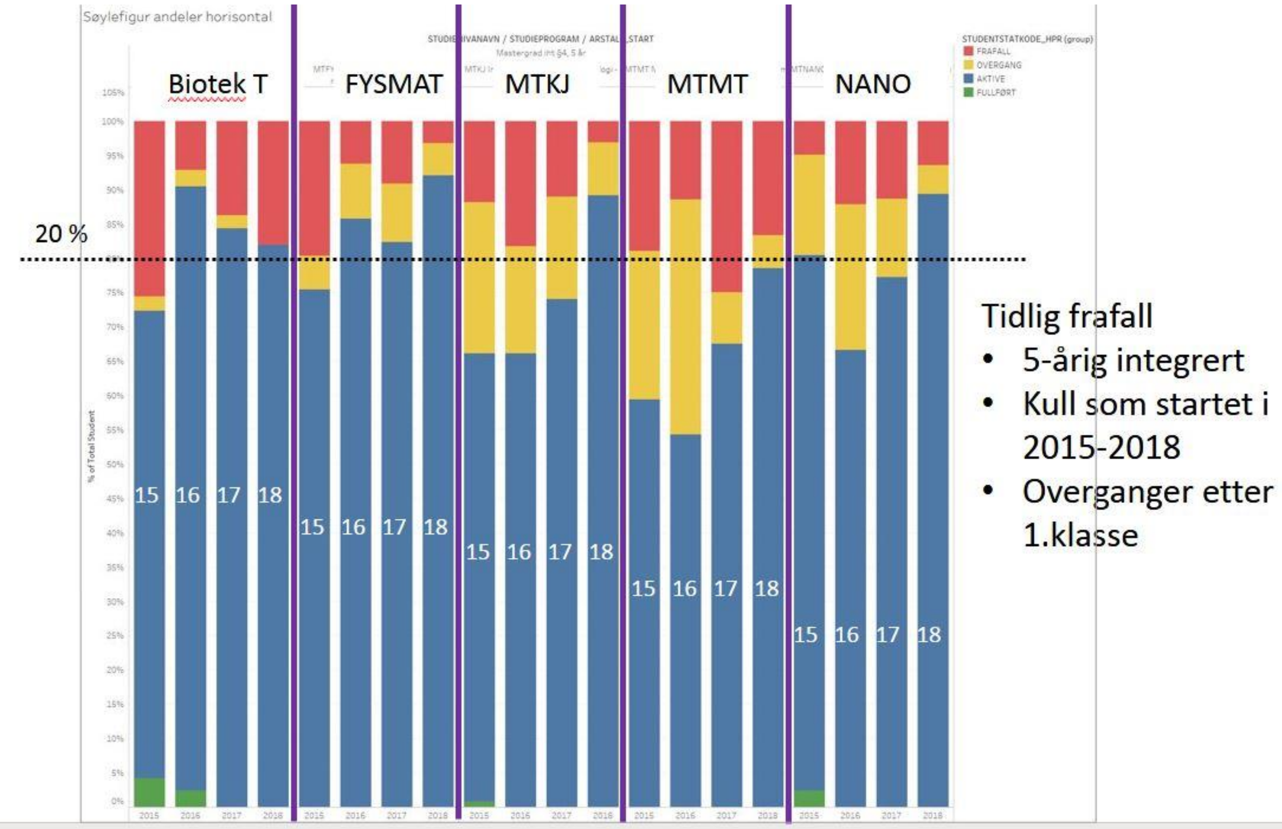


Figure 6 Early abandonment for 5-year integrated programs at NV faculty from 1st year students 2015 to 2018

Figure 7 illustrates the problem with abandonment (red), transfer (yellow), active (blue) and completed (green) students in all NV-faculty 5-year programs. MTMT had the highest % of transferred students.

Abandonment is also a significant problem in the 2-year international master program. Figure 8 below illustrates the students completed (blue), active (orange), transfer to other programs (grey), and abandoned (withdrawal – yellow). There was a high increase in the number of students from 2019. MSMT and MIMT were merged in 2019 and the number of students was merged into MSMT and is therefore giving a high increase for 2019 in Figure 8.

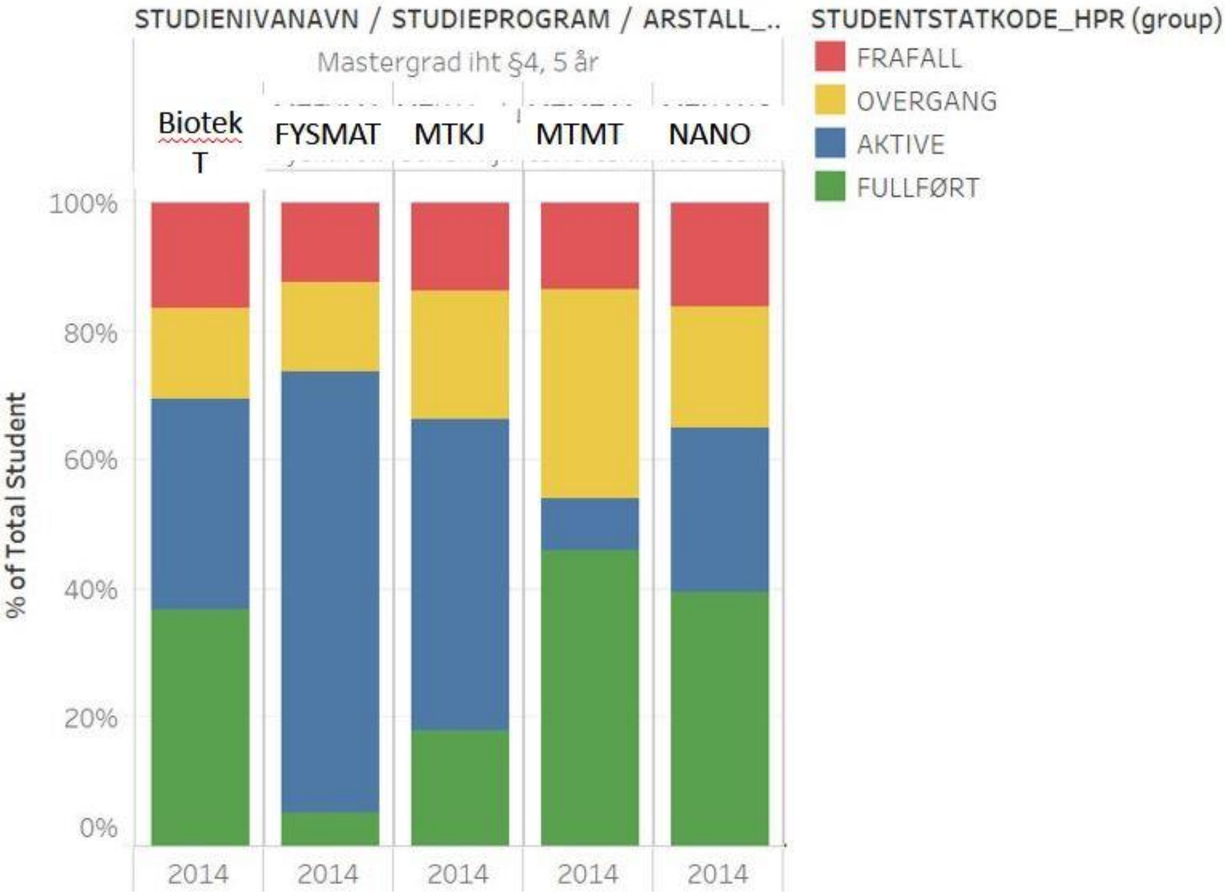


Figure 7. Abandonment, transfer, active and completed students in the 5 year programs at NV faculty for the 2014 students

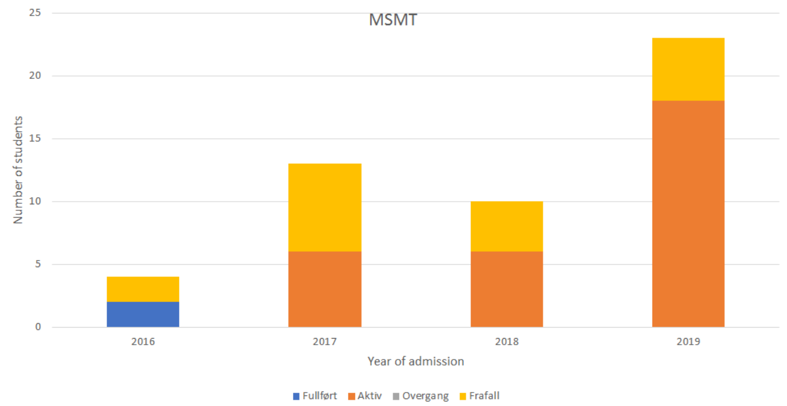


Figure 8 Abandonment in the MSMT study program. Orange is active students, yellow is abandonment and blue is completed students.

Quite a few surveys have been performed in order to understand and develop initiatives to prevent this large drop-out of students. Some of the student questions are also aimed at this providing further input, see Chapter 0.

The committee suggested a time scheduled weekly arrangement for the first-year students the first semester as an add-on to the course Introduction to materials science. This part of the course should contain motivating speeches and more information about "how to be a student" or awareness of courses that will come later in the study program. Some of today's measures, ex "Hva gjør en siv.ing.?", will be included in this. It was suggested that this would be approximately one hour each week, corresponding to the former "Fakultetets time".

6. "Fremtidens materialteknologistudium" 2013-2015

In this chapter, the background, mission and objectives of the *"New"* materials science and engineering program (MTMT) is briefly described. The outcomes of this previous revision are also provided. For more details, the readers are directed to a separate document authored by Ragnhild E. Aune, as well as the final report for the "New" program authored by Fredrik Steineke.

From 2013 to 2015 when the "new" M.Sc. program in DMSE was started, a plan of action was suggested to improve various aspects of the running DMSE educational program to produce engineers who possess capabilities as endeavoured by the objectives and outcomes of the "new" educational program.

6.1 Background

At NTNU there are several study programs that offer education to a large or smaller content within the academic area materials technology. The faculty of Natural Sciences hosts the two materials science and engineering programs MTMT and MSMT - as described in previous chapters. These programs have boundaries to a number of other study programs. At NV-faculty this is in particular the study direction "Materials chemistry and energy technology" in the 5-year integrated master study program MTKJ – Chemical Engineering and Biotechnology that offers many of the same courses within its four different specializations. Also, the study direction Nanotechnologies for materials, energy and environment in the 5-year integrated Nanotechnology master technology program has several of the same courses. The physics programs at NV faculty also have some overlap with the MTMT/MSMT programs especially within electron microscopy, functional and nanomaterials area. At the faculty of Engineering (IV) there are a number of courses offered that involves materials technology (i.e. TMM4100 Materials Technology, TMM4140 Mechanical Properties of Materials, TMM4160 Fracture Mechanics etc), which are part of various study programs. In particular the study direction Engineering Design and Materials (No: Produktutvikling og materialer, PuMa) in the study program Mechanical Engineering (No: Produktuvikling og Produksjon, PuP) have significant overlap to the MTMT/MSMT programs. Many students from the MTMT/MSMT programs are also recruited as master students (and later as PhD students) to projects in this grouping. Finally, also some activity within electronics, sensors and application of photonics are ongoing at the study program of Electronics at the faculty of information technology and electrical engineering (IE faculty), which are relevant for the MTMT/MSMT programs.

To ensure the production of highly qualified graduates within materials science and engineering, supporting Norwegian industry, public entities, academic institutions, and contribute to a sustainable development of the society through further development of the materials research and education in Norway. The overarching ambition for the project "fremtidens materialteknologi-studieprogram" was to restructure the education within materials science at NTNU through establishment of a new and strengthened 5-year master program in materials science drawing on the best practice available and fulfill emerging future demands to a materials science and engineering graduate.

6.2 Goals and strategies

The graduates of the *“new”* M.Sc. program in DMSE will be at the forefront of establishing, advancing, and expanding an indigenous knowledge base, which can be solidly relied upon for accepting future challenges, providing proper directions for industrial growth, and furnishing reliable solutions to engineering problems. Essential to this vision has been to secure that the Norwegian industry look inwards and explores the local talents, knowledge, and expertise in regard to seeking solutions to complex problems and finding answers.

The following goals with affiliated characteristics and strategies were put forth for securing the quality and advancement in the implementation of the "New" DMSE study program "Fremtidens Materialteknologistudieprogram":

6.2.1 Goal 1 (learning).

Be outstanding in developing and providing the highest quality M.Sc. learning environment in DMSE education.

Characteristics:

- Comprehensive academic and industry focused M.Sc. program.

- Learning environment conducive for accomplishing technical, ethical, and leadership skills.
- Enhanced learning experience through superior experimental and laboratory-based education and application of software tools.
- Improved critical thinking, team working, verbal and written communication skills, and awareness.

Strategies:

- Attract more students, especially those with higher-grade average into the M.Sc. program in DMSE.
- Continuously improve the quality of the DMSE curriculum and its delivery methods.
- Secure that the MSE student receives education in line with academic and industrial needs.
- Introduce critical thinking, teamwork and the art of communication during courses offered year 1-3.
- Establish interdisciplinary engineering educational courses/specializations.
- Attract and retain high quality faculty and supporting staff.

6.2.2 Goal 2 (education and research).

Be a world reputed DMSE responsible for providing a M.Sc. educational program in DMSE based on high quality basic and applied research.

Characteristics:

- Learning environments beneficial for carrying out basic and applied research.
- Partnership with local and national industry in education and research.

Strategies:

- Develop promotional material to publicize the M.Sc. program in DMSE to high school students.
- Expand the M.Sc. student recruitment in DMSE to achieve a critical mass (60-70) with students being recruited to further studies at both NV (natural sciences) and IV (engineering) faculties. This was intended (from NV's side) to be secured through a development of the program's first four terms, enabling easy transition to PUP study directions in year 3. A similar change for PuP was not attempted and effectively blocked a mutual transition of students between the programs.[8]
- Target recruitment of top high school students into the M.Sc. program in DMSE.

[8] More details about implementation of the new study program (2015) can be found in the final report authored by Fredrik Steineke.

- Develop an attractive recruitment and retention plan for the M.Sc. students in DMSE.
- Expand/improve research infrastructure to enhance research efforts in an educational setting.
- Develop and retain sound long-term partnerships with local and national (Norwegian) industry.

6.2.3 Goal 3 (industrial partnership).

Be a preeminent and leading institution for supporting the technological advancement and economic growth of the local and national industry in the area of DMSE in Norway.

Characteristics:

- Strong long-term partnership in education and research with local and national (Norwegian) industry.
- Enable student projects and M.Sc. thesis with active involvement from industry.
- Enable exchanges between department faculty and industry (experts/professor II).

Strategies:

- Further develop the collaboration with industry in regard to improving the curriculum of the M.Sc. program in DMSE, and setting up long-term research directions.
- Encourage industry-focused research projects for the M.Sc. thesis.

6.2.4 Goal 4 (human resources and infrastructure).

Be a leading environment in human-resource development and effective and efficient infrastructure utilization.

Characteristics:

- Sufficient number of classrooms, laboratories and student study rooms/places with individual desks to all 4-5 year students (students enrolled at NTNU and visiting).
- Fully equipped laboratories for teaching and student research.
- Upgraded and welcoming public areas and offices for M.Sc. students and DMSE staff.

Strategies:

- Increase support staff for smooth functioning of labs and other support facilities for educational and research purposes.

6.3 Improvement Actions

The mission of the academic staff involved in the study programs is to serve the students enrolled in the *"new"* MTMT program, as well as the Norwegian industry, by providing quality education with a strong foundation in:

- the fundamental principles of materials science.
- preparing students for leadership positions and successful careers in industry, research institutes, government, and academia.
- extending the knowledge base of materials science and engineering to support the competitiveness of existing industry and to spawn new economic development through active involvement in basic and applied research.
- providing professional development opportunities for practicing engineers through continuing education and other outreach activities.

Analysing the survey results and taking into account the learning outcomes and objective, the intended outcomes of the M.Sc. program in DMSE must be to continuously develop the program curriculum to facilitate improved student learning. Accordingly, a tentative action plan with recommendations for implementation was proposed to improve the program to better achieve its objectives.

6.3.1 Plans to improve the program

Actions concerning fundamental DMSE skills

Students must be prepared to use fundamental knowledge and skills acquired in coursework. They must be introduced to DMSE standards and practices. Recommendations for corrective actions within the constraints of the *"new"* curriculum were as follows:

- Revision of courses: courses description must be in accordance with the program objectives and outcomes. Special attention should be directed towards promoting DMSE concepts in the program as early as possible. Description of courses that have DMSE elements should reflect that in a clear and explicit way.

- Project oriented assignments and homework: serious efforts should be made to emphasize project-oriented assignments within courses especially for those having direct industrial applications.
- Using computer analysis software: students may be directed to use the available computer software in doing regular textbook problems and carrying out more elaborate DMSE oriented problems and/or projects. Using such programs will not only help the students to comprehend the subject material better, but also allow students to master the analytical techniques both of which are important parts in the DMSE area. Students should be shown how the software works in class or lab session, and by practice they can be much more productive, accurate, and fast which enables the students to try a variety of solutions when needed. Once the students are confident in using these tools, they can focus on solving DMSE problems and calculations in relevant courses.
- Industry collaborations: industry must be involved in enhancing the DMSE education by being members of the DMSE program advisory board, participating in guest lectures/seminars introducing the industrial perspective of the DMSE area to the students, providing information needed for use as case studies in an educational setting, offering real industrial projects as M.Sc. thesis work, etc. Other kinds of industry collaboration may include inviting DMSE engineer from industry to participate in selected courses and inviting professionals from abroad to deliver talks to motivate students as well as faculty during visits to the DMSE.

Actions concerning communication skills

It is very important in today's society to be good at communicating effectively in written, oral, and graphical forms. Recommendations for corrective actions within the constraints of the *"new"* curriculum were as follows:

- Skills in technical writing, and in effective speaking and listening, should be developed through extensive and frequent writing assignments, oral presentations, and participation in discussions in lectures, as well as in lab sessions if applicable. Homework assignments should contain certain amount of descriptive questions and/or essay problems or projects. Lab reports should emphasize individual descriptive writing rather than merely filling tables and drawing graphs. The standard format in technical lab reports including objectives, experimental, results, discussion, and conclusions should be enforced and graded accordingly. Graded reports should be returned to students for structure and grammar corrections if needed.

- Student's communication skills should also be improved though assignment of *e.g.* a project where the students present their work in front of the class and lecturer/instructor. This will also provide a floor for students' interaction and oral discussions by asking questions to the presenter.

- Writing communications skills should be developed by using technology in teaching. Digital assessment platforms (such as "*its learning*" from 2015-2018, and *"Blackboard"* from 2018) provide on-line and off-line discussion groups that allow students to disseminate ideas and express their views out of the classroom, and hence fully utilize the class time and enhance communication skills in and out of class.

- Encouraging students to attend seminars (*e.g.* SFI Metal Production Spring/Fall meetings) and have an active role in discussions about the topic of those seminars.

Actions concerning experimentation skills, effective lab utilization, and introducing more practical examples in DMSE courses.

Recommendations for corrective actions within the constraints of the *"new"* curriculum were as follows:

- A *"new"* and *"upgraded"* course in experimental techniques and procedures should be designed and made mandatory for all DMSE students. The DMSE should create conditions to develop the needed lab facilities and environments, as well as instructional material for both lectures and lab sessions of the course.

Actions concerning analysing and interpreting data

Recommendations for corrective actions within the constraints of the *"new"* curriculum were as follows:

- More experience should be provided in data analysis and interpretation. One of the main objectives for this is that the students should learn how to present and interpret engineering data, and to be able to develop functional equations using regression procedures and computer codes/commercial software.

- The lecturers/instructors of laboratory courses should encourage the students to complete analysis, and data interpretation related to a given experiment during the laboratory hours. Open-ended DMSE type problems that require thinking and the use of basic knowledge from year 1-3 courses is expected to encourage students to apply their knowledge and skills in thoughtful manners.

Actions concerning safety and environment issues

Students should develop awareness to safety and environment issues relative to the working place, and the local environment. Recommendations for corrective actions within the constraints of the *"new"* curriculum were as follows:

- Safety issues concerning chemical, electrical, high temperatures, and machine hazards must be discussed in relevant courses and labs.
- A code of safety procedures must be developed by the DMSE and be enforced on lecturers/instructors, students, and lab technicians.
- Lab sessions must include at least one session dedicated to safety issues related to the subject material.
- Impact of DMSE systems on the environment should be introduced in relevant courses.

6.4 Development of "New" Study Plan (2013-2015)

A large work involving many faculty members and student advisors at both faculties (NV and IV), industry and public enterprises (> 50 people altogether) chipped in with significant contribution in defining the new study program; course composition, courses and learning outcomes[9]. The concrete goal in the end was to develop a new study structure for the materials science and engineering program (the "New" DMSE program), by adjusting the first four terms of the study program MTMT to allow students to continue studies in the study direction Engineering Design and Materials (PuMa) within the program PUP. The students should therefore choose direction prior to year 3 (during 4th term) and continue studying more distinct pathways, either towards MTMT or PuMa. Several alternative study plans were discussed. The study plan previous to this revision is given below (Figure 9), followed by the final "New" study plan as agreed upon from the previous evaluation in 2015 (Figure 10). New students were anticipated to start in the new program from fall 2016 and the program should enroll larger pool of students (larger student groups), which should also lead to stronger and more resilient academic groupings.

[9] See the final report in the attached documents (only in Norwegian, but summarized in this chapter).

5V	TMT4905 **Masteroppgave** iht profil				**2. AVDELING**
5H	Komplementært emne	Valgfag iht profil	TMT4500 **Fordypningsprosjekt** iht profil		
4V	Eksperter i team	TMT4300 Lys og elektronmikroskopi	Valgfag iht profil	Valgfag iht profil	
4H	Komplementært emne	Valgfag iht profil	Valgfag iht profil	Valgfag iht profil	
3V	TIØ4258 Teknologiledelse	TMT4252 Elektrokjemi	TMT4210 Material- og prosessmodellering	Valgfag	**1. AVDELING**
3H	TMA4240 Statistikk	TMT4155 Heterogene likevekter og fasediagram	TMT4320 Nanomaterialer	Valgfag	
2V	TMA4123 Matematikk 4M	TMT4206 Strømning og varmeoverføring	TMT4130 Uorganisk kjemi	TMT4276 Grunnleggende termodynamikk	
2H	TMA4110 Matematikk 3	TFY4120 Fysikk	TMT4240 Metallenes mikrostr. og egenskaper	TMT4177 Materialteknologi 3	
1V	TMA4105 Matematikk 2	TMT4110 Kjemi	TKT4116 Mekanikk 1	TMT4176 Materialteknologi 2	
1H	EXPH0001 Filosofi/vit.teori	TDT4105 Info.tekn., gk	TMA4100 Matematikk 1	TMT4171 Materialteknologi 1	

Color codes: **Basisfag (obl.), Ikke tekn. fag (obl./valgbare), Obligatoriske MT-fag, Valgbare MT-fag, Spesialfag (valgbart)**

Figure 9 Study plan prior to Fremtidens materialteknologistudieprogram (< 2014)

5V	TMT4905/TMM4911/TMM4940 **Masteroppgave** iht profil				**2. AVDELING**
5H	Komplementært emne	Valg/obl iht profil	TMT4500//TMM4511/TMM4550 **Fordypningsprosjekt** iht profil		
4V	Eksperter i team	TMT4300 Lys og Elektronmikroskopi	Valg/obl iht profil	Valg/obl iht profil	
4H	Komplementært emne	Valg/obl iht profil	Valg/obl iht profil	Valg/obl iht profil	
3V	TIØ4258 Teknologiledelse	TMT4252 Elektrokjemi	Valg/obl iht profil	Valg/obl iht profil	
3H	TMA4240 Statistikk	TMT4155 Heterogene likevekter og fasediagram	Valg/obl iht profil	Valg/obl iht profil	
2V	TMA4123 Matematikk 4M	TMT4206 Strømning og varmeoverføring	TMT4130 Uorganisk kjemi	TMT4276 Grunnleggende termodynamikk	**1. AVDELING**
2H	TMA4105 Matematikk 2	TFY4120 Fysikk	TMM4XXX Produktutvikling Nytt	TMT4XXZ Materialfremstilling Nytt	
1V	TMA4110 Matematikk 3	TMT4110 Kjemi	TKT4126 Mekanikk	TMT4XXY Materialteknologi 2	
1H	EXPH0001 Filosofi/vit.teori	TDT4105 Info.tekn., gk	TMA4100 Matematikk 1	TMT4XXX Materialteknologi 1	

Color codes: **Basisfag (obl.), Ikke tekn. fag (obl./valgbare), Obligatoriske MT-fag, Valgbare MT-fag, Spesialfag (valgbart)**

Figure 10 Study plan agreed upon in the Fremtidens materialteknologistudieprogam evaluation. Also reducing number of specializations down to 2.

6.5 Changes in study program content from 2015 till today

This chapter describes the changes done to the study plan as a consequence of significant happenings during the process of defining the "New" DMSE study program: "Fremtidens materialteknologistudieprogram" (6.5.1), the changes requested by academic groups with strong connections to the program, planned changes in accordance with "New" DMSE study program, and as requested by the Executive Committee for Engineering Education (FUS) (6.5.2). Finally, the changes implemented and announced due to the recent merger with three university colleges in Norway (6.5.3.), including professional integration (courses assigned to discipline groups/departments), and consequences for learning outcomes (6.5.4.).

6.5.1. Implementation and immediate changes in the study plan

The Study program PuP was not able to implement any of the suggested changes to their study program, not being able to assist PuMa and MTMT in establishing a mutual transition of students between the two programs. The reasoning for this is not clear, but the effects are obvious. The study program MTMT (and MSMT) proceeded with making many of the suggested changes independently of PuP development. In other words, the original requirement was for students to be able migrate (and actually be transferred to the other program) freely both ways, giving enrolled students a broader selection of possible specialization and educational pathways. This free migration was still introduced reciprocally, but students have almost exclusively only migrate from MTMT/MSMT to PuMa[10].

At the IV faculty a big re-organisation of the department structure was initiated in 2016/2017 as part of the merging of NTNU with the HIST, Høyskolen i Gjøvik and Høyskolen i Ålesund. One result was merging of departments. The new Department of Mechanical and Industrial Engineering (MTP) is one example covering the two old departments “Product development and Materials (IPM)” and “Production and Quality Engineering (IPK)” in addition to parts of HIST. The Study program PuP is a common program between the MTP, Department of Structural Engineering (KT) and Department of Energy and Process Engineering (EPT). This means that the PuP program is very wide and that a lot of different topics (courses) covering the three involved departments need to be included in the program. Since the number of mandatory courses are limited in the study program it has not been able to include mandatory courses from the MTMT study program. However, optional courses are included in the program. The result is that it is not possible for students to be transferred between the two programs as was the original discussed idea. However, students can move between PuP and MTMT for their specialization projects and the master thesis project.

MTMT/MSMT both offered and continue to offer a wide variety of courses from IV-faculty and relevant departments (TMM-courses), while no TMT (Department of materials science and engineering) courses are offered in the PuP study program (except a joint course in corrosion and two "engineering courses from other study programs"[11] (TMT4301 and TMT4166)).

The immediate changes to the study plan in the development of "New" MTMT study program in the Fremtidens materialteknologiprogram:

- Materials Technology 1-3 (TMT4171, TMT4176 and TMT4177) was changed to the three courses, TMT4171 (not significant changes, but emphasis on "more than just metals")

[10] Only 1 student has gone from PuMa to MTMT
[11] All students in a 5-year integrated technology master programs must choose one engineering course from a different study program in their 8th term (4th year, spring).

TMT4178 (more applied materials science) and the new course TMT4345 Materials Processing. The text book by Callister is central in the first two courses and M. Tangstad (ed.), "Metal production in Norway" in the new course.

- TMM4XXX Produktutvikling (Product development) was replaced with a new course: "TMT4340 Materials and sustainable development".
- The three original study specializations (profiles) were kept, renaming the "Metals production and recycling" to "Resources Energy and Environment". Students think this name is misleading and that it should be changed again. Further discussions and a final new name should be discussed in the study program board.

6.5.2 Later changes in the study plan till 2018/19:

- A larger selection of elective courses has been introduced in the 3rd, 4th and 5th year.
- TMT4155 Heterogenous equilibria and phase diagrams and TMT4320 Nanomaterials are no longer compulsory in the 3rd year fall term for all profiles.
- Each specialization/profile has two profile-directed mandatory course in fall term 3rd year.
    - Profile "REM": TMT4155 Heterogenous equilibria and phase diagrams and TMT4306 Metal Production – Fereroalloys, Iron and Steel TMT4215 Casting is made
    - Profile "MB": TMT4240 Microstructure and Properties of Metals and TMT4215 Casting (Casting also moved from spring to fall term)
    - Profile "MFE": TMT4155 Heterogenous equilibria and phase diagrams and TMT4320 Nanomaterials
- Courses being offered in 3rd year have been removed from list of elective courses in 5th year to ensure progression in the specialization/profile.
- Number of complementary courses are set by "FUS" and has been reduced significantly
- A premade list of recommended "engineering courses from a different study program" has been introduced
- TMT4300 Light and Electron Microscopy has been replaced by the new course TMT4301 Materials Characterization.

6.5.3 Coming and commenced changes due to the merger with university colleges

NTNU recently merged with selected university colleges (Sør-Trøndelag university college, University college Ålesund and University college Gjøvik) and the Dean Resolution of academic integration (faglig integrasjon) was reinforced:

- TMT4206 Fluidflow and Heat Transfer, Introductory Course was replaced by the similar course TKP4100 heat and mass transfer from spring 2019. The new course is currently offered by the department of chemical engineering.
- TMT4276 Basic Thermodynamics will be replaced by the similar course TKJ4202 Chemical Thermodynamics from spring 2020.

Both these courses have been run jointly with the materials science version of the courses but with a four weeks discrepancy in the thermodynamics course. In the latter, MTMT students have had more metallurgical thermodynamics while the chemistry students have had electrochemistry. MTMT students have a separate mandatory electrochemistry course later on in the study (TMT4252 electrochemistry) so no learning strings has been broken.

6.5.4. Changes in Learning outcomes:

A large process, coined "the reaccreditation process", was carried through in 2018-19, involving documentation of various aspects of education and research for quality insurance in all listed and previously self-accredited study programs. Large emphasis was put on defining new learning outcomes in all study programs to better reflect the true competence, knowledge and skills acquired by the graduates. The learning outcomes should then be linked to the various courses and activities, as well as documentation of research performed and pedagogical education of involved faculty members.

The new learning outcomes are, by large, entirely rewritten and given in chapter 0. The original broad learning outcomes established in the Fremtidens materialteknologi evaluation were:

- to provide a solid foundation for the students in mathematics, basic chemistry, thermodynamics, physics, mechanics, heat and mass transfer, as well as scientific and engineering knowledge/skills that will serve students throughout their careers.
- to provide students with skills to enter the workplace well prepared in the following core competencies:
    - programming/modelling ability
    - open-ended problem solving ability
    - experimental and data analysis techniques
    - teamwork experience

  - oral, written, and multimedia communication skills
  - experience with modern computing systems/software's and methodologies
- to provide students with knowledge relevant to DMSE in general, including ethical, professional, social and global awareness, the impact of materials science on society, the importance of continuing education and lifelong learning in both technical and non-technical areas.

A set of measurable outcomes in the MTMT/MSMT programs has been appealed to ascertain that the educational expectations are met, and that the graduating students are capable of displaying certain skills and capabilities that will reflect on their performance as DMSE engineers, *i.e.* the graduated students shall have the ability to:

- apply knowledge of mathematics, chemistry, thermodynamics, physics, mechanics, heat and mass transfer, as well as scientific and engineering fundamentals to DMSE problems.
- identify, formulate, and solve practical DMSE problems.
- conduct experiments to study different DMSE systems, including various modes of operation, performance evaluation, properties of materials and manufacturing techniques, as well as to use laboratory instruments and computers to analyse and interpret data.
- use modern tools, techniques and skills necessary for practicing DMSE, including computational/software tools, statistical techniques, and instrumentation.
- work in a professional DMSE environments, and to understand the associated economical considerations.
- communicate effectively in written, oral, and graphical forms, including the use of professional-quality visual aids.
- work effectively in teams, including multidisciplinary teams, to solve engineering problems relevant to DMSE.
- understand the professional and ethical responsibilities of DMSE engineers.
- understand the impact of DMSE on the society and environment.
- recognise the need and an ability to engage in lifelong learning of DMSE.

The outcomes are the by-product of the learning objectives of the M.Sc. program in DMSE, and the two is interrelated.

6.6 What has worked and what did not work

One of the main objectives with Fremtidens Materialteknologistudie was to encourage interchange of students between PuP and MTMT. This has turned out to not work very well, as the MTMT students tend to choose subjects and assignments at PuP, but not vice versa. This goal was in addition partly been disrupted by the NTNU restructuring in 2016.

The student abandonment during the first year has not decreased in the way that was wanted. The main reason for leaving the study program has been poor communication about the diversity of materials taught, as the main focus the first year is on metals. However, the intake limit has increased and the number of students applying has increased for MTMT. This is a result of the recruitment campaigns directed at social medias.

The restructuring of the study program with a more coherent learning outcome through the first two years have worked well. Several new courses were introduced including more sustainability, more social relevance and up to date knowledge. In many ways have Fremtidens Materialteknologistudie been a successful project and has renewed the study program.

7. What do the students think?

7.1 Survey from current students

199 current students in the study programs MTMT, MIMT and MSMT, were asked to answer a survey about the study program, and we got 108 responses.

Current students were asked if they thought the name of the study program is appropriate.

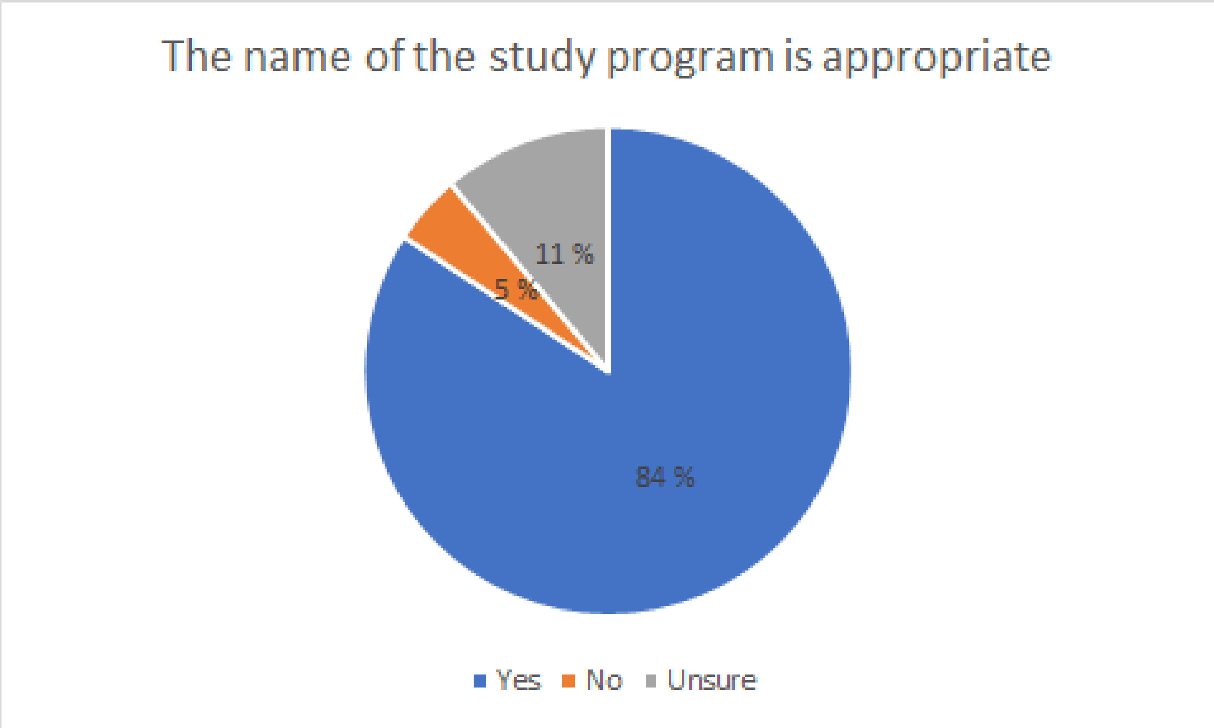
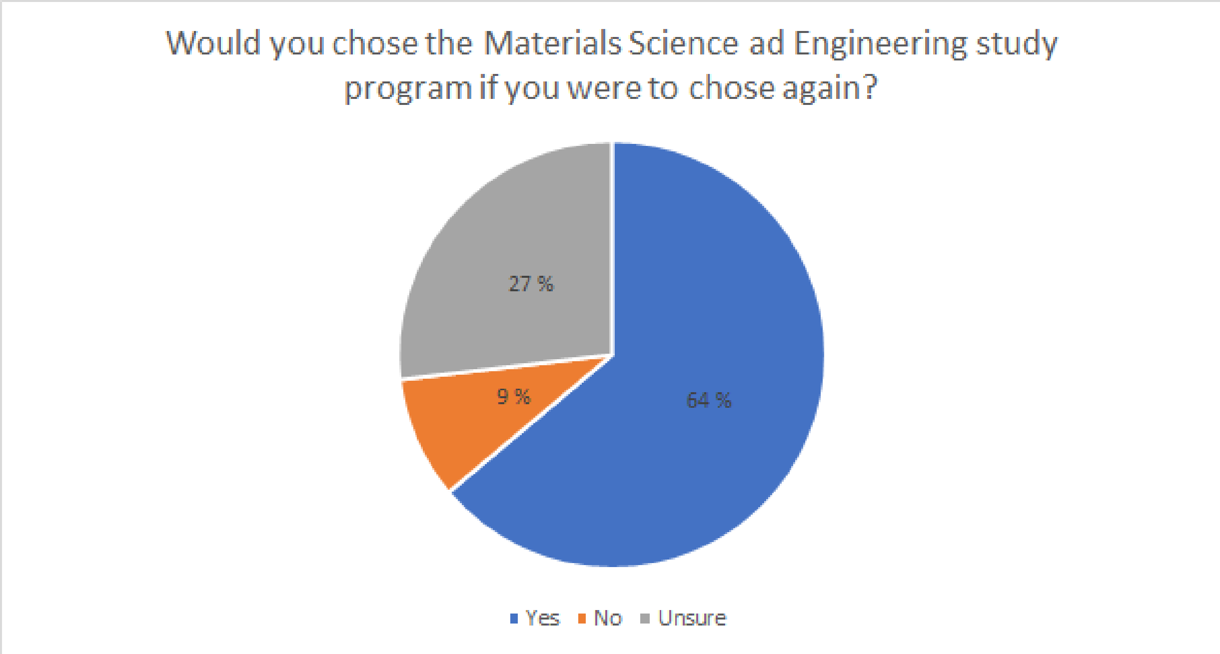


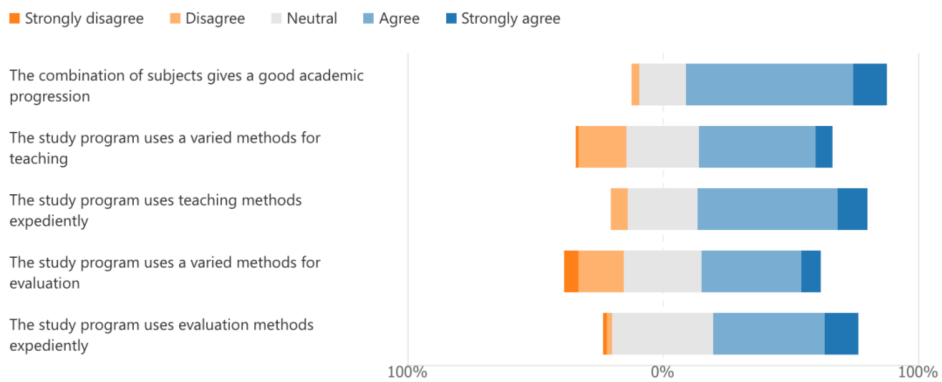
Figure 11 The current students was asked if they though the name of the study program is appropriate. The majority answered yes.

Suggestion for possible other name options; Metallurgy or Material Science and Metallurgy. The students pointed out they think there are a big focus on metals, rather the other materials. The name could therefore be misleading.

Current students were asked if they would choose Materials Science and Engineering, if they were to choose again:



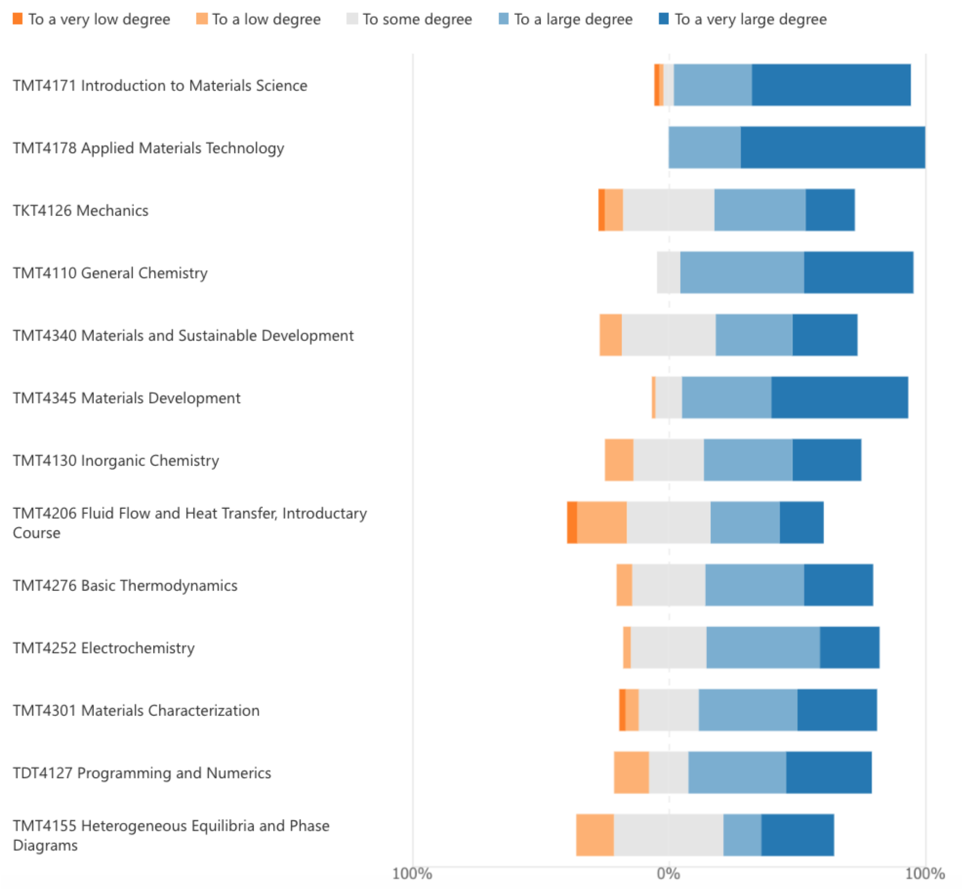
The current students were asked several questions about teaching and evaluation in the study program.



The students were asked to what extent they found the common subjects useful. The subjects taught in the higher grades have less responses than the ones taught in the lower grades, as not all students have been through these courses yet.

TMT4206 Fluid Flow and Heat Transfer, Introductory Course and TKT4126 Mechanics stood out as courses that are seen as less useful. TMT4155 Heterogeneous Equilibria and Phase Diagrams was also seen as less useful, but here the number of answers was much lower.

TMT4171 Introduction to Materials Science, TMT4178 Applied Materials Technology, TMT4110 General Chemistry and TMT4345 Materials Development stood out as subjects that are seen as the most useful.



The current students were asked what they have had the most use of from the study program and the introductory materials science courses were mentioned 8 times. The class TMT4178 Applied Materials Technology was mentioned another 6 times and TMT4171 Introduction to Materials Science was mentioned 4 times. Other classes such as TMT4110 General Chemistry (6), TKT4126 Mechanics (5), TMT4240 Microstructure and Properties of Metals (5), TMT4345 Materials Development (4) and TMT4276 Basic Thermodynamics (4) also stood out. Laboratory work (6) and project work (4) was also emphasized as good parts of the study program. Additionally, several students mentioned programming subjects such as TMT4210 Material and Process Modelling (3), TDT4110 Information Technology, Introduction (3) and TMT4260 Modelling of Phase Transformations (2) or just programming in general (2).

When asked about the least useful subjects, EXPH0004 Examen Philosophicum for Science and Technology was mentioned 8 times. TKT4126 Mechanics (7), TMT4206 Fluid Flow and

Heat Transfer, Introductory Course (5) and TMT4130 Inorganic Chemistry (4) were other classes that were frequently reoccurring in the answers.

8. Relevance for working life

The study program in materials science and engineering provides the educated candidates with a strong common theoretical framework, necessary for performing work as materials science experts in relevant industry and public entities. The success of the study program, providing the students with relevant working life experience, are based on several contributing factors: i) learning outcomes that are strongly influenced by the close interaction with industry, including many laboratory and practical exercises, ii) large selection of industrially relevant elective courses, iii) lecturers with previous job experience in industry, iv) guest lectures from industry, v) significant exchange and internships, vi) project and master thesis work in collaboration with industry or industry funded project, vii) active student union that increase student-industry enterprises interaction through for example the annual symposium “Materialdagen” and viii) excursions to relevant industry. In addition, the study program board has two representatives from relevant external enterprises, directly contributing to the learning outcomes of the program and program courses.

The study program and the various courses involved in the program are strongly influenced by external enterprises and joint activities, which will be important also in foreseeable future. Many students in the study program take advantage of the strong links to industry and international contacts through joint supervision of project works, internships between school terms and international exchanges. Effective research mentorship is higher education at its best and exchange of graduate students with joint supervision ensures strong and long-lasting connections and collaboration.

Specifically, hands-on experience through the study program is put forth as an essential part of the study in materials science and engineering. Laboratory activities are important parts of many of the program courses. The following mandatory courses contains a laboratory or research active part:

TMT4171 Introduction to Materials Science (including a full week of excursion to relevant industry)

TMT4110 General Chemistry

TFY4104 Physics

TMT4130 Inorganic Chemistry

TMT4276 Basic Thermodynamics

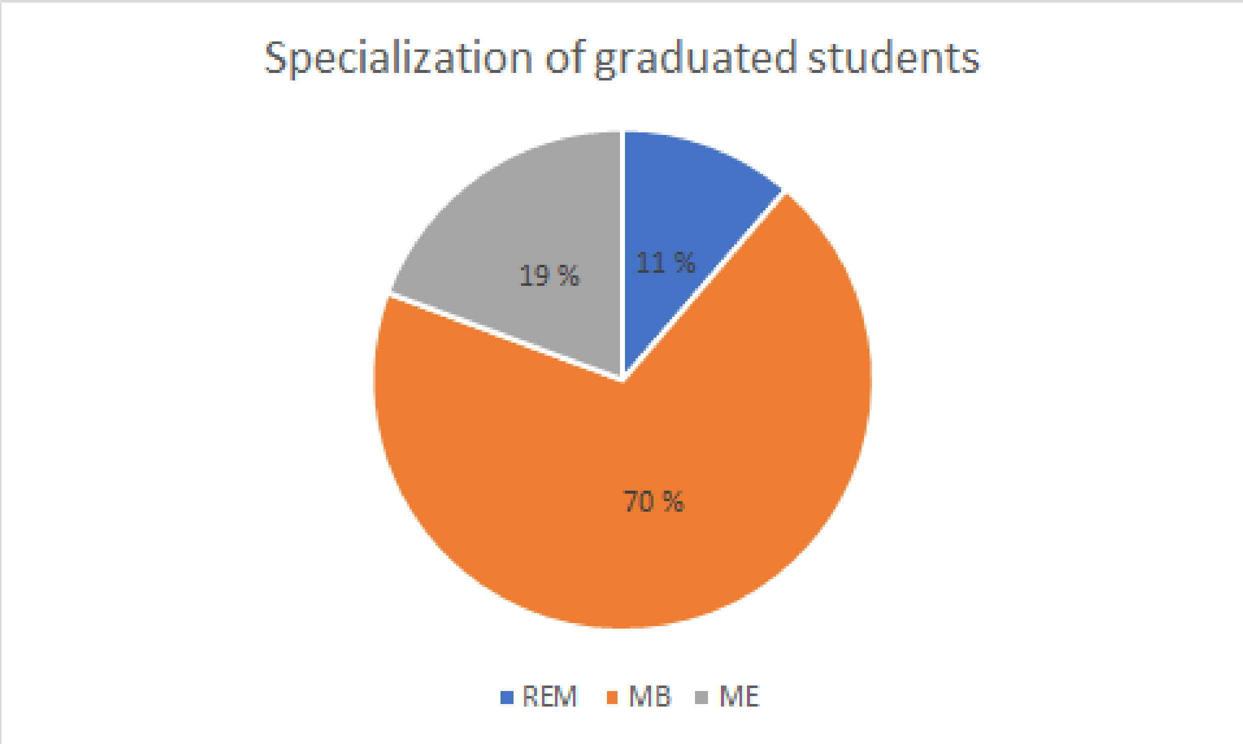
TMT4345 Material Development

TMT4301 Materials Characterization

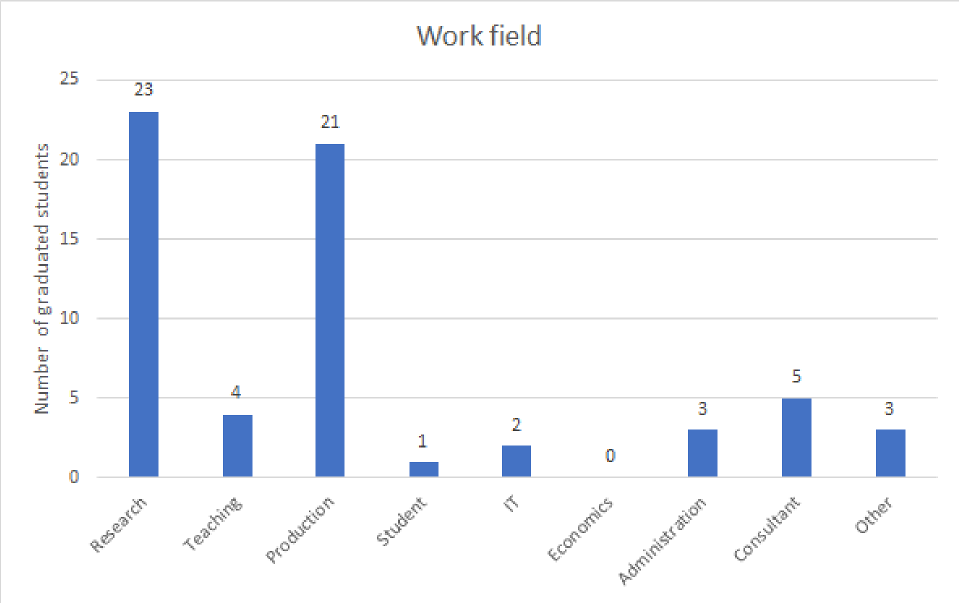
8.1 Alumni survey

124 alumni were also asked to answer their own survey, where 62 answered.

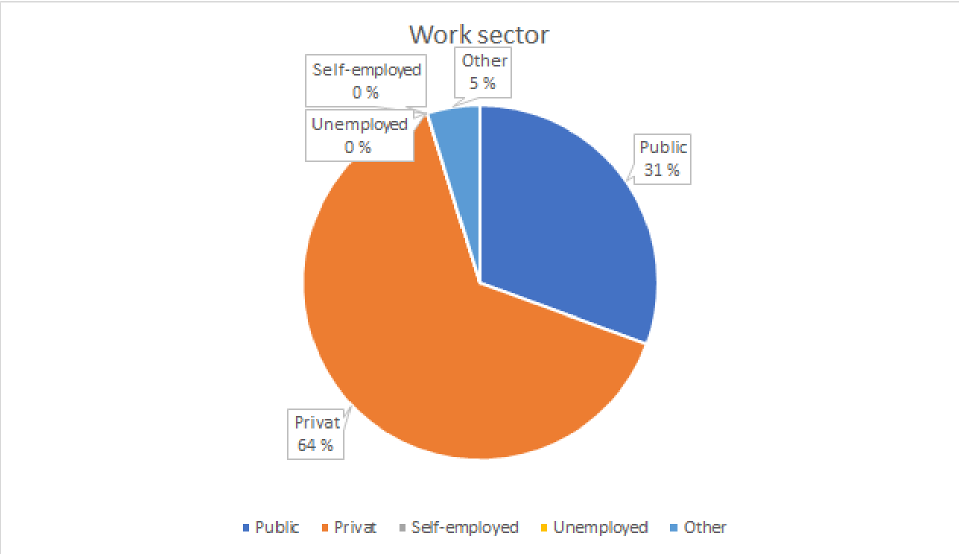
Among those who answered, the majority graduated with the specialization Materials Development and Use (MB)



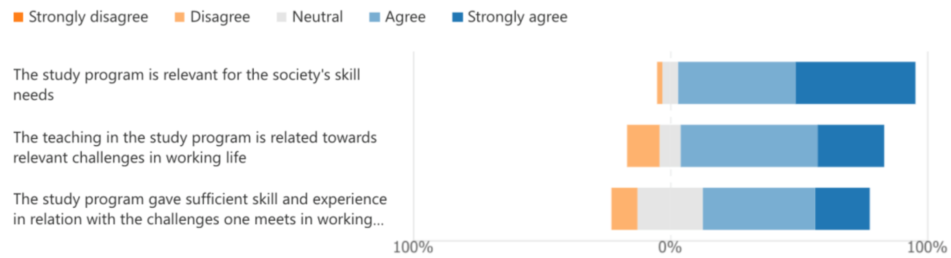
The alumni from our study program are divided into different work fields, where research and production are the main fields:



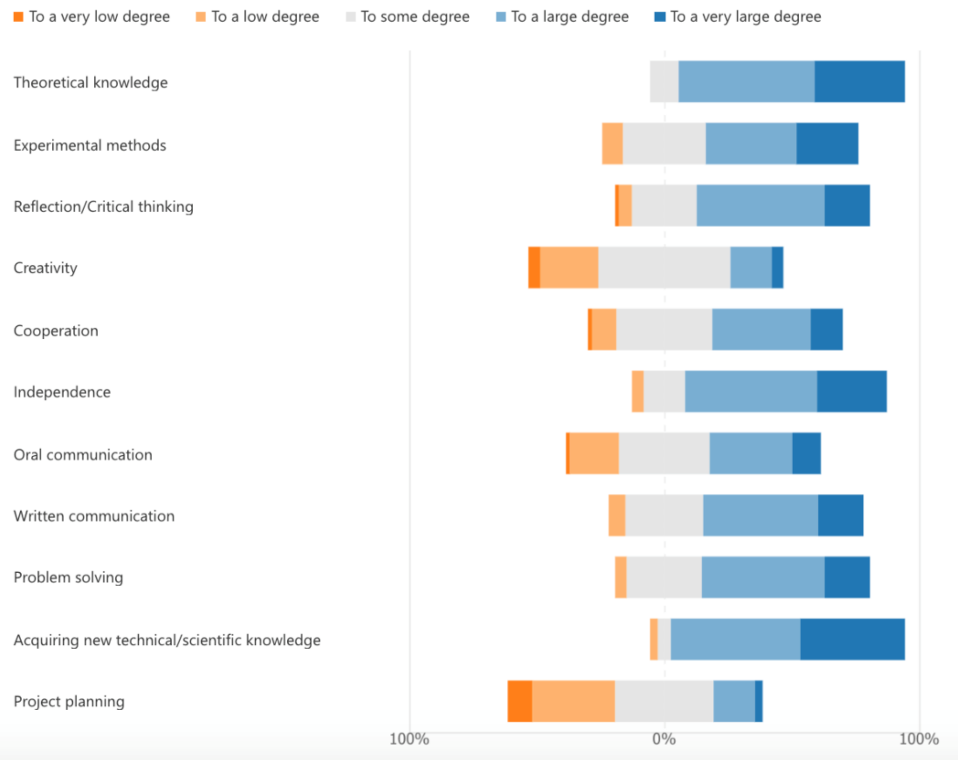
Most are working in the private sector, but also many in the public sector:



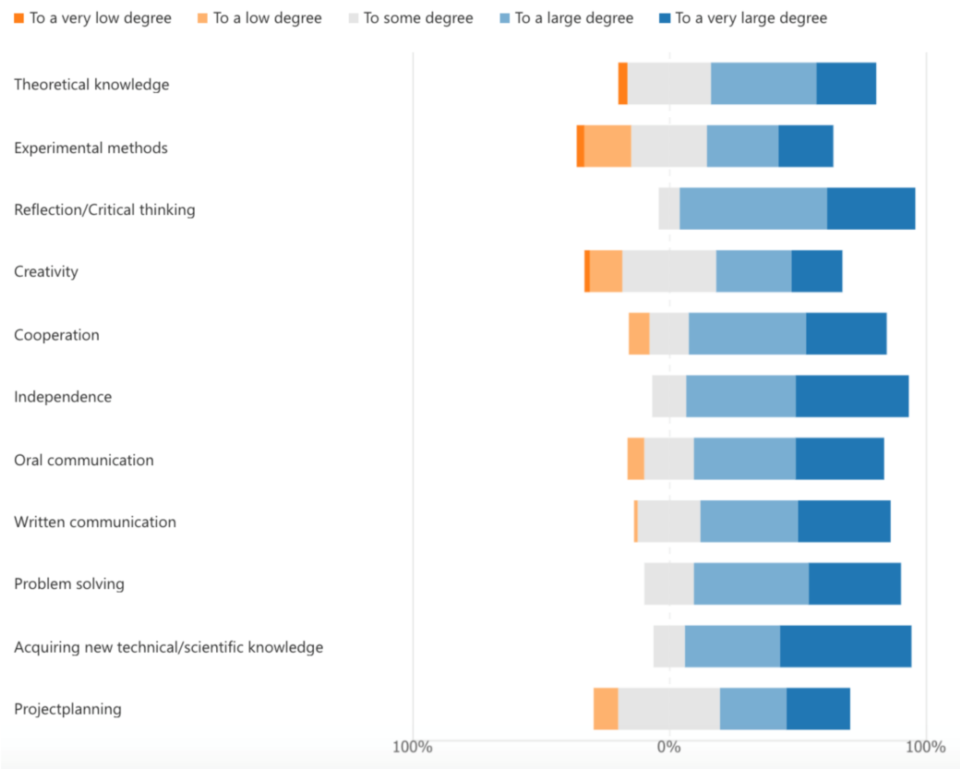
The former students were asked about the society and work relevance. Most either agreed or strongly agreed that the study program is relevant for the society's skill needs. Most also agree that the teaching in the study program is related towards relevant challenges in working life and that the study program gave sufficient skill and experience in relation with the challenges one meets in working life. However, there is a bigger percentage that disagrees with these statements.



They were also asked to what degree they feel the study program has contributed to developing their abilities within the following fields. The study program gets especially good evaluations on theoretical knowledge, independence and acquiring new technical/scientific knowledge. However, it scores quite poorly on creativity, oral communication and project planning.



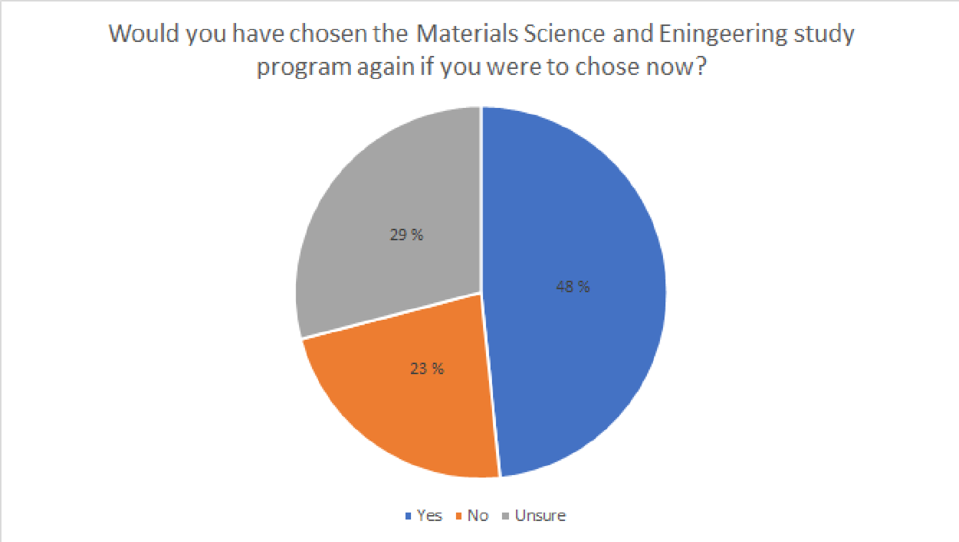
And then they were asked how much they have used the following knowledge from the study program. Most students stated that they had used all fields either to a large degree or to a very large degree, but experimental methods, creativity and project planning were seen as the least useful fields.



The alumni were also asked what subjects they have found most relevant and useful for their work experience. TMT4240 Microstructure and Properties of Metals was mentioned the most with 13 mentions. Other classes that were also mentioned frequently was TMT4255 Corrosion and Corrosion Protection (10), TMT4276 Basic Thermodynamics (8), TMT4300 Light and Electron Microscopy (7), TMT4210 Material and Process Modelling (6), TMT4242 Steel Offshore (6), TMT4245 Electrochemistry (5) and TMT4222 Mechanical Properties of Metals (5). Other than that, the project work and or master's thesis was mentioned 9 times.

Both TMT4155 Heterogeneous Equilibria and Phase Diagrams and TMT4320 Nanomaterials were each mentioned 7 times as the least useful subjects. TMT4130 Inorganic Chemistry (4), TMT4206 Fluid Flow and Heat Transfer, Introductory Couse (4), EXPH0004 Examen Philosophicum for Science and Technology (4) and mathematics classes (4) were also mentioned more frequently than other subjects.

When asked whether they would choose DMSE if they were to choose again, the answer was the following:



Whether this reflects a discontent with the study program and working life, or just a possibility to choose another field of interest is not specified.

9. Summary

The study program is well in line with the strategy of NTNU and the NV faculty, especially with respect to the sustainability goals. It could be stronger with respect to digitalization, e.g. learning and using industrial software tools. When it comes to innovation and entrepreneurship, the study program lack courses that directly stimulates to this.

In the fall 2015 the "new" materials science and engineering study program started up. Some minor changes have been implemented after the start up in order to motivate the students with the right combination of courses each semester as well as making sure that the courses build upon each other. One of the main objectives with the project and the revision of study program in 2014 was to allow for closer collaboration with the study programs at the Engineering faculty and to encourage students to interchange between the study programs. Already during the project process, it was not possible to come to an agreement for the necessary basic courses the first two years to allow for free interchange between the programs and, hence, this is room for improvement at this point.

The working life relevance was mapped through a survey to alumni. Most either agreed or strongly agreed that the study program is relevant for the society's skill needs. Most also agree that the teaching in the study program is related towards relevant challenges in working life and that the study program gave sufficient skill and experience in relation with the challenges one meets in working life. The tool box consisting of theoretical knowledge, ability to acquire new technical/scientific knowledge combined with critical thinking is what the students bring with them from the study program. Graduates and industry would like the students to be offered a course about welding.

10. Action plan

Both programs are evaluated each fifth year as part of the quality assurance system at NTNU. With the background in the evaluation the following actions are suggested. The study program will do a halfway evaluation around June 2022 to ensure the progress of the action plan.

10.1 Short term goals

What	**Who**	**When**
Recruitment – there should be a focus on metals, so that the students don't feel mislead when they start their study.	Faculty and recruitment team	Spring 2020
Good lecturers in study program courses in the first year are important	Department	Spring 2020
Course about "How to be a student" the first semester for the first-year students. This should be intertwined with activity in the first year materials science course	Program coordinator, Lecturer in the introduction course	Autumn 2020?
Change the name of study track 1: "Resources, Energy and Environment"	Study program	2020
More individual practise in writing reports. Short reports to make it easier for the students and the course coordinator.	UU	2020
Possible to change the semester for Exphil	Study program	
Smaller groups for laboratory exercises	UU	Spring 2020
Heat and Mass transfer, the feedback from the students should be given to the course coordinator. The relevance of the course should be more clarified in the study program.	Course coordinators/UU	Spring 2020
Follow up of course reports. A new system for evaluating and reporting on	UU	Spring 2020

the courses should be developed. Today system does not work well.		

10.2 Long term goals

What	Who	When
More digitalization – possible to with some of the existing courses with different calculation/modelling/computer programs	Faculty/Study program	2021
Find a solution to the cooperation with PuP	Faculty/department	2021
More coordinating between the course-coordinator that is teaching the same students on semester. Ex.: Mathematics and IT GK should be implemented in Materials Science course the first semester for MTMT	UU/study program (work group)	2021
MSMT • Change the elective courses. Maybe less elective courses • Change the elective courses for bachelor Materials Science to help the transition for the master • Create a type of "Summer School", making it possible	Study program board	Start-up 2020 but implement 2021

for the students to take the missing qualifications • Facilitate for applicants with a bachelors degree from mechanical engineering		
More project-based courses	UU	2021
Welding course	UU	2021
Halfway evaluation	Study program	June 2022

Appendix – results from the survey

Current students

What have been good:

Valgemnet korrosjon. Mener dette burde være et fellesemne da dette er noe alle materialteknologer burde kunne noe/mye om.
Bredde i fagene og mulighet til å velge spesialisering. Fagene med få studenter har absolutt gitt best utbytte.
Tverrfagligheten som følger av fellesemnene, spesielt mekanikk og materialfagene gir god innsikt i hvordan moderne strukturer blir designet for å tjene sine hensikter effektivt og lenge.
Praktisk rettet undervisning fra faget Eksperimentell material- og elektrokjemi
Materialfremstilling
Fagene Anvendt mattek. og materialfremstilling
Programmeringsfagene, material- og prossesmodellering og modellering av fasetransformasjoner. Metallenes mikrostruktur og materialteknologi 2 (som nå heter anvendt materialteknologi).
Material og prosessmodellering, mekanikk, kjemi, materialfremstilling, termodynamikk
Materialteknologi 1, 2, 3 og 4
Lab
Fag med fokus på programmering. Prosmod og Fasmod.
Termodynamikk og elektokjemi
Lab og påfølgende rapportskriving
anvendt, kjemi, materialfremstilling, mekanikk
At det er bredde i fagene de første årene. Jeg tror elektrokjemi kan vise seg å være nyttig i fremtiden.
Innføringsfagene i materialvitenskap, samt mekanikk og termodynamikk.
Eksursjon i 1.klasse.
kompetansen fra ITGK
Materialteknologi-fagene, materialkarakterisering, kjemi og fysikk, korrosjon og korrosjonsbeskyttelse
Fag undervist fra instituttet, ikke de generelle som matte, statistikk etc.

programmering og numerikk, grunnleggende termpdynamikk, innføring i materialvitenskap og anvendt materialteknologi.
Anvendt
Har mye utnytte av labene og ekskursjonene. Det er først når man ser det i praksis at man skjønner hvordan ting henger sammen.
Forelesninger med Hans Jørgen
Prosjektoppgaver
IT Grunnkurs, Strømning og varmeoverføring - sommerjobb, Materialer og bærekraftig utvikling - sommerjobb
Metallurgirelatert kunnskap
Innføring i materialvitenskap
Metmik
Kjemi
Alle kjemifagene.
HetLik, prosjekt i Mattek 2, Nanomaterialer, Støping, metallografikurs og alt av lab med unntak av den i fysikk. Mulighetene for jobb som læringsassistent og sommerjobb ved instituttet har også gitt mye læringsmessig utbytte, uten å være en del av studieprogrammet i seg selv.
Materialteknologifagene
Metallenes mikrostruktur og egenskaper, materialteknologi 1, mekanikk
Lab
Det mer analytiske synet på ingeniørvitenskap, ikke bare matte og beregninger, men mer visuelt og praktisk.
Fag hvor man lærer om metallurgi.
Elektrokjemi 1 og 2 Metallenes Mikrostruktur og Egenskaper Materialteknologi 1, 2 og 3
Lære om forskjellige materialkategorier og deres egenskaper og produksjonsmetoder, samt materialvalg og anvendelser.
Innføring i materialvitenskap
Prosjekter/ store øvinger som er rettet mot praksis
Anvendt Materialteknologi

Å samarbeide med andre studenter og å bli forelest i et relevant og bredt pensum slik at det er lett å trekke linjer mellom ulike emner.
Grunnkunnskapen jeg fikk fra innføring i materialvitenskap.
Bolken om funksjonelle materialegenskaper i anvendt materialteknologi var veldig spennende. Lab-opplegget har vært bra, får sett teori i praksis
Var kjekt å dra rundt å se på bedrifter
De grunnleggende materialteknologiemnene
fag som er mer spesifikke for det jeg interesserer meg i, som funksjonelle materialer og keramisk materiavitenskap. Også grunleggende materialteknologi fag + uorganisk kjemi
Allsidigheten, men skulle gjerne hatt flere valg fra tidligere av
Valgfagene samt den generelle grunnkompetansen du får fra de første 2 årene
Bacheloroppgaven.
Fremstilling, egenskaper og bruksområder ved ulike materialer
Forståelsen av forskjellige vitenskapsfager , deres bindelser mellom hverandre. Også lærte jeg å jobbe i kollektivt og å bli en selvstendig student.
Prosjekt i tidligere materialteknologi 2. Man fikk bestemme tema selv og ha et stort prosjekt tidlig. Var veldig motiverende og lærerikt.
Grunnlegende informasjonsteknologi
Metallenes mikrostruktur og egenskaper
Gode relevante gruppeprosjekt som går over hele semesteret der man faktisk jobber som om man skulle gjort i virkeligheten og anvende kunnskap til virkelighet, ikke bare huske og pugge til eksamen.
Programmering, numerikk, løsing av ligningssystem med matriser (Matte 3), uorganisk kjemi, Gibbs fri energi og aktivitet, viktige egenskaper til materialer, hvordan man generelt produserer materialer, innblikk i praktisk arbeid og forskning
chosen subjects toward specialization, and some software introduction
Programspesifikke emner
Grunnleggende materialteknologifag og kjemi/mekanikk
the options to choose electives
obtaining good knowledge of industrial process, good lab equipment, good atmosphere
Metalproduksjon
Corrosion and Trinology lectures

What have not been good:

Exphil have been meantion several times.

Uorganisk kjemi og nano
Fellesemnet "Heterogene likevekter og fasediagrammer", mener dette er et fag for de som velger hovedprofil "Materialer for energiteknologi".
Exphil, matte 4 og TMT4330 ressurser, energi og miljø. Det siste er det aller dårligste faget jeg har hatt på NTNU. Lite forberedte forelesere og "svevende"/udefinert innhold ble ikke bedre i kombinasjon med "tvunget oppmøte".
Strømning og varmeoverføring
Uorganisk kjemi
Lang introduksjon før faglig start i innføring i materialvitenskap.
Introduksjon til material teknologi, sine 3 uker med innføring i materialverden
Exphil
Organisk kjemi
Biologi
Matte 2, exphil
Store deler av termodynamikkfaget som ble undervist sammen med kjemi. Har heller ikke fått spesifikt brukt for mekanikk selv om forståelsen er grei å ha. Tror dette er mer nyttig på hovedprofil 2.
Exphil. Enkelte av mattefagene har vært nyttige, men de er veldig dominerende ifht andre fag og tar utrolig mye tid (øvinger, maple, innleveringer). Dette medfører at andre, spennende og mye mer relevante fag blir nedprioritert.
Assignments that does not count for the final.mark
EXPH0004 Examen philosophicum for naturvitenskap og teknologi
Strømning
Uorganisk kjemi, elektrokjemi.
Matte 3
Føler at jeg har hatt nytte av alt. Bare noe mindre enn annet
Programmering og mekanikk
mye fra mattefagene og exphil
Mekanikk (mindre nyttig)

Flere fag som virker mindre nyttig, men ingen som var helt ubrukelig.
REM (faget), Mekanikk, K2
Nanomaterialer, Materialer og bærekraftig utvikling, Materialfremstilling
Kanskje mekanikken, litt for mye bygninger, litt for lite makronivå.
I stor grad Materialteknologi 3-faget.
ITGK-bøker.
Faget strømning og varmeoverføring, grunnkurs.
Exphil, matematikk 1,2,3,4. Statistikk, teknologiledelse.
Strømning og varmeoverføring, med untak av noen få grunleggende prinsipper. Mekanikk også
hetlik var vel 80% repetisjon?
Kanskje, noe fager hadde hatt litt betydning for meg f.eks mekanaikk, strømning og varmeoverføring. Derfor bruker jeg ikke kunnskaper fra disse fagene.
Hatt bruk for det meste, men uorganisk og mekanikk har vært minst relevant for min del.
materialfremstilling og materialer og bærekraftig utvikling som separerte fag
Matematikk 2
exphil ITGK - Svært lite relevant fordi vi ikke lærer ting som man trenger til vanlig ingeniørarbeid; plotting, numerikk (kommer i matte 4 og da er alt helt nytt), simuleringer osv.
Å kunne masse detaljer om hvordan diverse gamle filosofer (f.eks. Platon) så på verden. Jeg mener likevel at mye av exphil-pensumet er nyttig.
Et halvt årsstudium i matematikk
I think EiT course can be shorter, maybe not a whole semester.
Materialer og bærekraftig utvikling

Final comments from current student:

Det er dumt for mtmt at mimt (hist) får samme grad på tross av å ha gått et mye enklere løp

Flere valgfag på høstsemesteret, i år var det veldig lite å velge mellom for oss som går i 5. Kunne vært bedre tilrettelagt (samarbeid?) for at man kan ta materialfag på maskin osv, info om hva som finnes.

Materialkarakterisering burde bli et mer kurs-basert fag for å lære seg å bruke karakteriseringsteknikker og ikke handle så mye om oppbygningen av utstyret og hvordan lys brytes. Noen forelesere burde bli MYE flinkere til å undervise.

Bra sosialt miljø

Synes opplegget med å velge profil er litt rart, til syvende og sist er flere av emnene på flere av profilene og ut i fra emnene man velger kan man bevege seg ganske langt fra profilnavnet. Hadde vært lettere å bare velge fra alle fagene og ikke ha forskjellige hovedprofiler

Mer om polymere kanskje, blir litt vel mye metaller

Fordel å ha generell kjemi før eller samtidig som mattek intro. For eksempel ha kjemi istedenfor exphil første semester.

Ville vært interessant å lære mer om koraner og polymere på tidligere nivå

4. semesteret er meget omfattende, og burde vurderes ut ifra faktisk arbeidsmengde studentene bruker (overskrider ofte oppgitt arbeidsmengde i faget).

Vi trenger mer programmering, gjerne innenfor de ulike materialteknologifagene. I til leggvarmere må vi ha lærere, ikke bare professorer. Kjersti, som vi har litt i materialframstilling, er et godt eksempel på en god lærer. Mer av sånne som henne, og gjerne allerede i de første fagene

Muligheter av valgfag og k-emner har vært veldig snevert, og jeg skulle ønske jeg kunne velge mellom flere alternativ av k-emner slik som andre ingeniørprogram.

Kunne tenkt meg å ha et teoretisk fag om sveising.

Ønsker et bredere spekter av materialer på et tidligere tidspunkt i studiet, var et stort fokus på metaller det første året. Synes for eksempel solcelle fag, og hydrogen fag bør komme tidligere inn i studieløpet.

Bør komme tydeligere frem hvor stort fokus det er på metallurgi de første årene. Det overrasket mange og førte til unødvendig stort frafall. Synes det kunne kommuniseres bedre.

Kvaliteten på undervisningen og veiledningen som gis varierer veldig mye mellom forskjellige undervisere/veiledere. Det virker ikke som om instituttet stiller krav til eller følger opp at disse gjør jobben sin i møte med studenter. Når det gjelder veiledere fører dette til at studenter har veldig forskjellige forutsetninger for å levere gode prosjektoppgaver og masteroppgaver.

Kanskje informere studentene mer om hvilke muligheter de har til praktiske prosjekter på materialbygget, bruk av labber og instrumenter. Kanskje til og med oppfordre til private prosjekter og grupper som kan gi en mer praktisk tilnærming til emnet. Feks arrangere kurs i maskinering som en del av studieløpet, slik at studentene får en mer praktisk forståelse til prosessene materialene skal gå gjennom, ikke bare teori, men ekte forståelse.

Jeg ble overrasket i starten av studiet at materialteknologi-fagene fokuserte mest på metaller. Dette burde kanskje komme tydeligere frem i deskripsjonen av studiet. Andre materialer, for eksempel funksjonelle materialer, lærer man først om etter litt. Dette skulle gjerne visst når jeg valgte studiet.

Likte Solceller og Fotovoltariske Nanostrukturer Burde lære mer om polymere, keramer og kompositter

Generelt mye rot, lite strømlinjet og dårlig kommunikasjon mellom ulike faglærere og fagkoder.

Var litt mye overflødig tid under teknostart. Kunne vært planlagt bedre.

Jeg tror det hadde vært en god ide å ha bedre forelesere i introduksjonsfagene til materialteknologi, da inntrykket i disse fagene bestemmer om folk har lyst til å fortsette (basert på samtaler med førsteklassinger). Generelt er det stor variasjon i hvor gode foreleserene er, men jeg mener at de bedre bør ha introduksjonsfagene for å hindre at forl mister interessen med en gang.

Veldig varierende kvalitet på undervisningen fra ulike forelesere

Faget strømning og varmeoverføring burde utbedres med fokus på å bygge på tidligere kunnskap studentene har lært som omhandler studiet.

Selv om enkelte fag er unyttige for meg betyr ikke det at alle syns det. men jeg tror mange ønsker noen av disse fagene til å endre seg slik at de blir mer nyttige og lærerike, mange fag er ganske dårlig satt opp (spesielt Strømning). Hadde vært greit om flere av vurderingene hadde en effekt på den endelige karakteren. Eksamen kan telle 60-70% men om man har veldig mye tidkrevende lab arbei og store øvinger bør dette arbeidet være verdt mer i den endelige karakteren. man risikerer dårlig karakter om man jobber hardt i hele semesteret men har en dårlig dag på eksamen eller er uheldig med eksamens timeplanen og har alt på en gang.

Skulle gjerne få kunnet velge fag på min egen master. Føler nå at det sitter en mann på toppen som tar de fleste valg...

Veldig fornøyd men gjerne mer undervisning i materialteknologi og itgk

I Material- og prossesmodellering og modellering av fasetransformasjoner burde vi ha lært mer om numerikk og mer på forståelse enn bare hvordan man lager fine program i Matlab og Excel. Eventuelt hatt et nytt fag som går mer på grunnforståelse for materialmodellering og hvordan løse ulike problemstillinger knyttet til det å lage en datamodell av et materialfenomen.

Endre fagplan slik at ikke vår 2.klasse har alle de verste fagene i ett semester. Høst 2.klasse må spre ut mat.tek labbene/prosjektene så man ikke sitter med 5 rapporter som skal inn 2 uker før eksamen. Mer fokus på andre ting enn bare metaller, spesielt bare Al og stål. Studiet heter materialteknologi, men 80% er metall. Skjønner det må til i starten fordi det er lettest, men er nå i 3.klasse og har hatt kanskje 4 fag som er mer eller mindre bare metall og fortsatt ikke et eneste om polymere, keram, kompositt, funksjonelle (utenom et par kapitler i andre fag som ellers mest handler om metaller) Ikke vær så sta med fagene for linjene, la studenter kunne prøve å lage sin egen vei med å blande fag man selv synes er interessant.

Alumni

What have been most relevant and useful in your work life

Elektrokjemi, termodynamikk
Korrosjon og grunnleggende materialfag
Metallets mekaniske egenskaper og masteroppgaven
Metallproduksjon of Ferrolegeringer
Metallenes mikrostruktur, materialmodellering, teknologiledelse, Strømning og varmeoverføring, mekanikk 1,
Materialteknklogi 1,2,3, Material og Overflatekjemi, og valgfagene jeg tok
HMS i tungindustrien // Grunnleggende Termo // Hetlik // Rafinering og resirkulering
Matematikk 1-4, Statistikk, Fluidflow and heat transfer, thermodynamics and phase diagrams, material and process modelling, modelling of phase transformations, casting
Korrosjon og korrosjonsbeskyttelse
Mattek 1-3, met.mik, korrosjon, utmatting, prossmod
Elektrokjemi, basic metallurgi, basic termodynamikk, modellering, labarbeid og -rapporter
Stål offshore. Materialets mikrostruktur
TMT4905 Masteroppgave; TMT4276 Grunnleggende termodynamikk; TMT4130 Uorganisk kjemi
Generelle emner for materialvalg og begrensninger
Stål offshore, korrosjon, bruddmekanikk, utmatting,
Elektrokjemi, korrosjon, kjemi, materialteknologi
Elektrokjemi, metallproduksjon, termodinamikk, bruddmekanikk
Matte 1, IT grunnkurs, Grunnleggende termodynamikk, strømning, lys og elektronmikroskopi
Solceller og fotovaltaiske nanostrukturer, fordypning/masteroppgaven
Mastern, itgk, prossmod
Polymerer og kompositter
Materialteknologi, mekanikk
Metallurgi, aluminium og stål
Programmeringsfag.
Fag som omhandler faktorer som definerer eigenskapene til dei ulike materiala, samt samspelet mellom materialer og miljø for å forstå trugsler og barrierer er sentrale for meg.

Stål offshore, metmik, elektrokjemi, korrosjon, tribologi og lys og elektronmikroskopi. Materialteknologi 1,2 og 3 var svært nyttige for å etablere oversiktsforståinga.
Metallenes mikrostruktur, material- og kjemispesifikke fag
Eksperter i Team.
Metallenes mikrostruktur og egenskaper
Laboratorietunge fag
Korrosjon
TMM4260 Offshore materialer, TMT4240 Metallenes mikrostruktur og egenskaper, TMT4242 Stål offshore, TMT4255 Korrosjon og korrosjonsbeskyttelse, TMT4320 Nanomaterialer
EiT, Keramisk Materialvitenskap, Masteroppgave, Statistikk
TMT4306, TMT4326, TKP4160, TMA4255, KP8105, TMT4208, TTK4130, TPK4115
Lys- og elektronmikroskopi, metallers mekaniske egenskaper, metallers mikrostruktur og egenskaper, teknologiledelse, statistikk, heterogene likevekter og fasediagram.
MetMik, MetMek
Ingen spesifikke emner. Alle i like stor grad, tror jeg.
Metallproduksjon, prosessmodellering og fasemodellering
Mattek 1 og 2, Met.mik., Stål offshore, korrosjon, forming og støping, bruddmekanikk, material- og produkttesting.
Prosessmodellering, grunnet samarbeid og problemløsning
Keramisk materialvitenskap
Prosjekt- og masteroppgave
Teoretisk kunnskap
korrosjon
Tribologi og overflateteknikk, korrosjon og stål offshore
Mattek 1,2,3,Støping, termodynamikk og fasediagram, metallenes mekaniske egenskaper, metallforming, metallenes mikrostruktur og egenskaper, prosjekt og masteroppgave, lys og elektronmikroskopi
Mattematikk, modellering av fasetransformasjoner
Masteroppgave, prosjektoppgave, lys- og elektronmikroskopi
Met.mik, met. Mek, bruddmekanikk, lys elmik, het. Lik. Tribologi
Metallenes mikrostruktur og egenskaper
Kjemi av alle typer og prosjekt/masteroppgave

Kunnskap om materialer og produksjonsprosesser. Matematikk er også viktig
casting course and Scanning electron microscopy course

What has not been relevant or useful in your worklife

Exphil have been mentioned by several

Alle økonomifag o.l.
Lysmikroskopi faget
Ex-Phil
Støping
Vitenskapelig kommunikasjon
Eksperter i team
ingeniøremne fra annen linje,
Matematikk, fysikk, avansert metallurgi/termodynamikk
Nanoteknologi
TMT4320 Nanomaterialer
Termodynamikk, støping og generelle metallprodusjonsfag.
termodynamikk, statistikk, hetlik,
Strømningslære
Nanomaterialer, exphil, uorganisk kjemi
Exphil, teknologiledelse, finans
Heterogene likevekter og fasediagram
Kjemi
Metmik..?
Eg trur dei aller fleste har vore nyttig, anten direkte eller fordi dei etablerte ei forståing eg kunne byggje videre på.
Matte, fysikk, it
Strømning og varmetransport
De rent teoretiske fagene
TMT4155 Heterogene likevekter og fasediagram
Matte 2-4, Fysikk, Heterogene likevekter
TMT4166, TMT4130, TMT4252

Ex.phil, elektrokjemi, strømning og varmeoverføring, generell kjemi, nanomaterialer.
Uorganisk kjemi, korrosjon (tok bare korrosjon fordi det var det eneste som passet i timeplan)
Nanomaterialer, el.kjem., het.lik,
Nanoteknologi, orbitalkunnskap osv har jeg hatt lite bruk for
Solceller brenselceller og hydrogenteknologi
TMT4155 Het.Lik.
Prosjektplanlegging
Uorganisk kjemi og strømning og varmeoverføring
Heterogene likevekter, material og overflatekjemi,
Nano
Exphil
Eit
Eksperimentell material- og elektrokjemi
Matematikk på høyt nivå
Experimental Materials Chemistry and Electrochemistry

Final comments from the graduated students:

Materialstudiet er bra, men savner kanskje en mer praktisk tilnærming til utfordringer.

Problemet med studiet slik jeg husker det var mangel på struktur i grunnfagene og hos foreleserne som hadde fagene i 1-3.klasse. Mye kaos, og for mange som ikke var spesielt gode forelesere, bidro til at en god del sluttet. Hele spekteret av materialteknologifeltet ble ikke ordentlig presentert for oss før i 3.klasse, det var for mye fokus på metaller, uten å forklare godt nok at vi starter med det fordi det er enklest og for å lære grunnleggende begrep. Labene i mattek-fagene og påfølgende (met.mik, etc) var også ustrukturerte. Læringsutbytte og hvorfor vi skulle pusse/polere enda en metallbit og se på i lysmikroskop (og hvordan denne laben var forskjellig fra den forrige) kom aldri godt frem, og det var lagt opp til alt for mye selvstendigt arbeid for tidlig. En annen ting med labene er at de ikke drillet oss nok i rapportskriving tidlig i løpet så det kom som et sjokk i 5.klasse med prosjektoppgaven.

Har en ganske generell Designerrolle i min jobb, og har litt bruk for nesten alle fagene

Labarbeidene i mitt studieløp var lite seriøse. Det var store grupper som skulle levere rapporter sammen og man visste at det skulle lite til for å bestå. Dette gjorde at mye tid ble kastet bort på dårlig arbeid som egentlig ikke gå noe særlig utbytte eller motivasjon. Færre labrapporter som leveres av mindre grupper og har strengere krav ville vært veldig nyttig for å utvikle evner i både skriftlig og muntlig kommunikasjon, samarbeid, kritisk tenkning m.m. Tror kanskje dette ble endret for senere studiekull.

Studiet markedsfører seg dårligt. Lite kunnskap om behov for kompetansen blant mindre og mellomstore bedrifter.

Jeg synes at valgfagene i 4. og 5. klasse i liten grad bygde på eller komplimenterte hverandre. Jeg synes derfor det manglet en koherens og en helhet i spesialiseringen. Gjerne se på muligheten til å implementere noen dataemner i valgfaglisten. Dette tror jeg kan bidra til økt konkurransedyktighet når studenter skal søke jobb etter studier (mange jobbutlysninger ønsker dataferdigheter).

Av erfaring ser jeg at nesten alle bedrifter i privat sektor ønsker at ALLE ingeniører har kunnskap og ferdigheter i AutoCAD (tegneprogrammer) og Abacus (FEA). Dette mangler i MTMT da dette studiet er tungt rettet mot metallproduksjon. På mitt årskull, og de før meg var dette en linje nesten ingen valgte. Usikker på hvordan dette er nå, men MTMT bør styres etter hvor studentene ender I arbeidslivet og hvor mange som velger de forskjellige spesialiseringslinjene.

Arbeidslivet etterspør erfaring. Om ikke arbeidserfaring så kurs, lisenser og brukserfaring av konkret utstyr. Enkle forhåndslagde labkurs knyttet til fag er ikke nok, og man blir litt prisgitt utstyret man velger å bruke under arbeid av masteroppgaven. Det bør være åpnere fagoppgaver hvor man selv kan lære å spesialisere seg i noen metoder/ustyr til den grad at det kan skrives på cv. Evt utplasseringsperioder i bedrift. Sommerjobbpraksis fungerer ikke da det er for få sommerjobber og konkurransen er hard. Utplassering som del av fag, uten betaling, for å øke praktisk kompetanse er bedre!

Et fag om 3D-printing av metaller kunne vært interessant (dersom det ikke allerede finnes).

Savnet alternative undervisningsformer, det ble veldig mye forelesning + 8 av 12 øvinger godkjent, og det fungerte ikke for meg. Savnet å lære konkrete verktøy som industrien etterspør, som CAD og simuleringer. Savnet også en bredere tilnærming til materialteknologi, vi lærte nesten ingenting om polymerer og komposittter. Synes ikke vi ble *poteter nok, samtidig som det vi ble spisset på er en utdanning få i arbeidslivet har hørt om og tror kan være nyttig. Mistet interessen etter 2. klasse, men ble værende på grunn av studiemiljøet.*

Jeg synes fagutvalget de siste to årene er ganske begrenset.

Min opplevelse er at gav både bredere og dypere teoretisk kunnskap enn jeg trengte i min første private jobb, mens kulturen i bedriften og den jobbrelevante teorien må man uansett lære på jobben

Var veldig få fag en kunne velge mellom på profil 1 så vi fikk litt slakkere tøyler på det å velge fag fra andre fakulteter så lenge vi gikk målrettet inn for en spesifikk kompetanse. Det er noe av det jeg har tjent mest må i arbeidslivet ettersom IMT ikke hadde noen mer krevende fag innen prossessmodellering og regulering. Har også merket at vi har hatt alt for lite forskningsstatestikk. Vi har bare hatt et fag om usikkerheter generelt, men ikke noe om hvordan en faktisk skal bruke statistikk i en forskningssituasjon eller hvordan det brukes for kvalitetssikring. Her er det mye å hente, ettersom det er noe av kjernen i det å kjøpe og selge produkter samt å drive forskning.

Studiet gav meg ikke noe særlig med tanke på arbeidslivet, men det gav meg enormt mye i form av forståelse av fysikken og prosessene som styrer alt i verden og universet. Veldig givende

Materialutvikling og -bruk bør se mot PUMA og legge til rette for at man kan ta flere fag der. PUMA er etter min mening mye mer industri- og arbeidslivsrettet, mens de få "fys.met."-fagene som er igjen ved IMA blir for teoretiske og PhD-rettede. Og der bør tilbys et sveise-/sammenføyningsfag.

Studiet kan vinkles mer mot teamjobbing og prosjektjobbing. Også økonomifagene har store mangler i forhold til det man møter. Ledelsesfag er en mangel

Jeg ønsket meg mer praktiske oppgaver ila studiet, evt ved siden. Etter 5 år står jeg igjen med en kniv, en kubjelle og en støpt Trondheimsrose. Jeg forventet å ta tilgang til verksted osv for å lage ting i større grad.

not on high demand in the market