# Evaluation of the Engineering Education at NTNU

Review Team Report

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# Summary

Engineering faculties at NTNU provide a sound engineering education based on the lengthy experience gathered as NTH and maintained in the new structure as NTNU. The review team met committed students and professors forming a very good learning and teaching environment.

Nonetheless, as no perfect situation exists anywhere, some improvement still seems possible. Based on a thorough discussion of the documentation provided and as a result of the interviews the team recommends the following for internal reflection:

- The funding by the Norwegian government does not seem completely out of line. The financial problems, which undoubtedly exist, are obviously more of an internal and structural character.
- FUS should concentrate its activities more on strategic issues.
- The Programme Committees should be responsible for the quality of the courses and their structure. The Heads of Programmes should have the mandate to change teacher/ teaching methods.
- In general very conservative teaching methods are used. New approaches like project and problem based learning are recommended to be applied more frequently than currently in place. In addition the use of ICT in teaching and learning (experiments, simulations, examples, exercises…) should be developed and integrated.
- Based on the current financial and human resources structure, the number of programmes seems to be rather high. The overlap in content of some programmes is significant. Thus a distinct profile of NTNU is at risk. A critical review of the portfolio of programmes is recommended
- Industry would like to see an increased availability of candidates, particularly PhDs, from NTNU.
- The university needs to discuss whether it aims at securing its position as a national educational centre for Norwegian engineers, or whether its strategic goals for 2020 are to be achieved.
- The future development of engineering education in Europe should be followed closely by NTNU. If the harmonization efforts in Europe strengthen the case for a strict Bologna structure, NTNU should be prepared to adapt.
- The team recommends an opening of the NTNU character, carefully but continuously, towards a more university-like character.

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# 1 Introduction

From 14 to 18 April 2008 the review team visited NTNU's premises. According to a predefined programme, interviews with numerous stakeholders were conducted checking on the plausibility of the self-evaluation reports and collecting additional information to answer questions put forward by the Rector during the preparatory meeting in February 2008.

This report is structured into 3 main areas: Chapters 2 and 3 will provide a summary of the findings as well as statements of a general character that are valid for NTNU as a whole. Chapters 4 to 10 address all topics mentioned in volume I of the self-reported evaluation and amendments put forward during the kick-off meeting. An appendix contains concrete remarks regarding the 16 programmes mentioned in volume II of the self-evaluation report.

# 2 Resources and Culture

## 2.1 Management and Resources

A fundamental problem is always the assessment of the adequacy of the financial resources. Its perceived inadequacy was outlined to us in almost every interview. In order to comment on the current NTNU situation the review team considered the compilation of data for comparison. A thorough discussion of the data, however, made it clear that the individual funding systems all differ in detail. A calculation of a virtual benchmark with an arbitrary definition did not seem reasonable as its meaning would hardly be relevant.

Based on a rough interpretation, the review team came to the conclusion that the funding by the Norwegian government does not seem completely out of line. The financial problems, which undoubtedly exist, are obviously more of an internal and structural character. Independent from this assessment there is good reason to demand equal funding for the natural science and engineering curricula, as both are very intensive regarding laboratory experience. This financial increase is pivotal in order to ensure that the quality of the engineering programme can be maintained. This especially means that the experimental part must not be reduced any further.

NTNU has a big advantage in terms of the ratio of students/professor (16:1). In consequence the personnel costs are extremely high despite the moderate wages paid according to European standards (admitting the negligence of the local costs of living in Trondheim). Pages 11 and 12 of the supplementary report provide a table on money and costs allocated to teaching. According to this table, NTNU allocated about 47 million € (383 million NOK) to finance a total of 6135 60 ECTS units at the science and technology faculties (IME, IVT, NT) in 2007. As each student is supposed to study 60 ECTS per year, the number of units is equivalent to the number of financed student places for this year. According to the data from Berlin, these figures seem very plausible as the personnel costs necessary to educate 9000 students are almost identical when adjusted for the difference in size of the two institutions. The review team strongly encourages NTNU to strengthen its work in establishing meaningful international benchmarking of both its financial and other parameters.

In a more general way the following remarks should be reflected upon by NTNU: As a general recommendation the first 3 years of education should be input financed based on the number of students enrolled as agreed upon with the government. An output based financing

system should be applied only to the last two years. All budgetary data should be based on three year gliding averages to avoid imbalance due to volatility or external market influence.

## 2.2 The Culture at NTNU

NTNU is relatively young. The spirit of the old NTH is still very much alive and partially still governing the general atmosphere. NTNU is unique in Norway. This by itself poses chances and risks. Norway, as almost all other European countries, lacks and will lack graduates from the engineering and natural science programmes. This was already confirmed to the review team by the representatives of Norwegian industry. Consequently, as NTNU educates 80% of all engineering graduates in Norway at Master's level, the majority of staff members interviewed by us emphasize their dedication towards Norwegian students and their education for Norwegian industry.

On the other hand, NTNU has given itself strategic goals for 2020. The aim is to achieve international recognition and reputation and to be among the top 10 institutes of technology in Europe. In detail it is outlined that NTNU is to develop numerous joint degree programmes with other top 20 institutes of higher education in Europe. This aim goes far beyond the national perspective. It was the team's impression that there is a gap between an ambitious rectors' team and university board pushing towards these targets and an emphasis on meeting the demands of Norwegian business and industry at the professorial and staff level. This leads to a lack of strategic alignment resulting in obvious management challenges. These will be addressed more specifically in Chapter 8. The university needs to discuss whether it aims at securing its position as a national educational centre for Norwegian engineers, or whether the goals for 2020 are to be achieved.

Based on a long reputation for a high standard in engineering education over many decades, some of the changes involved in the merger to NTNU are regarded as negative by the staff. There still seems to a cultural gap between the engineering campus and the rest of the university, leading to somewhat defensive behaviour against further change within the engineering faculties.

The engineering education at NTNU has a tradition of a rather rigid structure for courses and study programmes. It is challenging to combine this with the characteristics of a true university: emphasizing critical and independent thinking and the development of the students' desire and ability to acquire knowledge. Teaching methods should play an important role (see Section 7.3), but there is also a cultural element in the attitude with which the students are met.

In education the picture of the engineer for the future has changed. The competences expected from a graduate in engineering call for a high degree of social competence and societal responsibility. If all decision making is taken from the students it will be more difficult to achieve these goals for them. The team therefore recommends an opening of the NTNU character, carefully but continuously, towards a more university-like character.

The students of NTNU are highly committed to their institution. They are well organized and highly committed to help newcomers to get along and become accustomed. This should be better acknowledged by the professors in terms of flexibility if voluntary functions conducted by students collide with the strict rules currently in place. NTNU would suffer from a severe loss if students reduce their voluntary commitments because of personal disadvantages.

Last but not least, NTNU should be more active on the political lobbying side. The fact that NTNU financed its demand for buildings and infrastructure from its own resources put NTNU at a financial disadvantage with regard to public funding which went to other institutions that needed investment in buildings and infrastructure. This shows that the government should have greater recognition of NTNU's importance to tertiary education in Norway. National industry and European sister organizations are prepared to help NTNU actively on this issue.

# 3 Relevance of the MSc Engineering Programme to the needs of the society

## 3.1 Balance of educational activities supporting development of knowledge, skills and general competences.

If the balance of educational activities and the resulting level of competencies is to be assessed then this comes close to the general definition of a programme's evaluation. As this cannot be performed in depth in 5 days for 16 programmes, indirect benchmarks must be used, knowing that they are subject to bias. One possibility is to take the feedback from the job market as critical indicator.

In meeting representatives of key Norwegian businesses, we noted a consensus that NTNU should offer a thorough education of science and engineering fundamentals. In addition, industry expected candidates to have skills in abstract thinking and a good basis for further learning. Inter-disciplinary communication skills were seen as vital, while early specialization was not recommended. The industry representatives, although supportive of the integrated five-year programme, were critical about the high number of specialized programmes of study now offered.

In the current Norwegian job market, there is a lack of qualified technical personnel. Industry, therefore, would generally like to see an increased capacity for most engineering disciplines, provided this does not reduce the quality of the candidates. Some of them said that candidates from NTNU no longer are unique, but often have to compete with very good candidates from other universities in Norway and abroad. They also raised questions about the current entrance criteria to NTNU as possibly limiting the availability of potentially good students. Industry would like to see an increased availability of PhD candidates from NTNU, while recognizing that their own recruitment and wage policies give no financial incentives for students to continue to PhD level. Some industries support PhD partnership programmes to stimulate more PhDs in their relevant fields. They also recognized NTNU's challenge in recruiting qualified senior personnel in the future, and recommended an increased use of adjunct professors as a partial answer.

Despite the fact that the general programme structure seems to reflect the desired emphasis on fundamentals the representatives from industry mentioned that certain deficits regarding basic engineering knowledge of NTNU graduates (citation) "..are undeniable". According to some students the learning objectives at the programme level are not clearly defined. This indicates that the content needs to be critically reviewed and that certain teaching methods may need adaptation.

As mentioned above, industry emphasizes that training in soft-skills such as social competencies and communication skills must be an integral part of a modern engineering programme. According to some observations, the graduates, leaving NTNU today, show significant deficits in these competences. In the review teams' opinion this is not a surprising. The inadequacy of some of the non-technical subjects provides one direct explanation. Furthermore, teaching methods and culture do not sufficiently stimulate independent and critical thinking, and dialogue. In order to ensure long-term competitiveness of their students NTNU should follow up this criticism.

## 3.2 Number of programmes of study within the MSc in Engineering degree at NTNU, including comprehensiveness and contents of the programmes

Based on the current financial and human resources structure the number of programmes seems to be rather high. The overlap in content of some programmes is significant. That way a distinct profile of NTNU is put at risk, and students are driven to select specialization very early, on a limited (and in some cases slightly misleading) basis. In addition there currently exists great danger all over Europe that the number of master's programmes is becoming extremely high and that the graduates from such courses are narrowly trained specialists. These graduates thereby have never gained the flexibility to take jobs in other than their specialized areas.

The main risk, however, is that programmes offered are more "marketing driven" rather than "market driven". Two arguments have been presented for the high number of programmes: Attracting more and better students by offering "cool", modern subjects, and the possibility to introduce the applied subjects early on in the programme, knowing that the students are already dedicated to one particular field. The most prominent example at NTNU is "Nanotechnology". It remains an open question if there will be enough employment offers for the graduates or if it would be wiser to train material scientists with a focus on nanotechnology, which can be identified by industry with the help of diploma supplement and transcript of records. Properly handled, such an approach may still give NTNU marketing opportunities, while avoiding selection of a narrow specialty at a too early date.

We recommend a critical review of the portfolio of programmes, with the aim to offer fewer admission level programmes. The programmes, which are retained after such a review process, should provide possibilities to select specializations at a later stage. If new programmes are considered for NTNU it should be mandatory to consider the cancellation of an existing programme.

## 3.3 Capacity of the MSc Engineering Programme in total and for the various programmes of study

It is the impression of the review team that the number of students to be enrolled is a given number defined by the government. As part of the lobbying process described above negotiations should be initiated with the government to increase current figures. The current number of students is too small to fulfil market needs as well as the NTNU demand for young scientist who do research on their way to a PhD. Industry today would like to see an increase in candidates in most disciplines and graduates at master's and PhD levels.

The finances necessary to educate more students have partially to come from the government as extra funding but probably also from NTNU internally when the above outlined discrepancies have been straightened out. The budgetary model currently in place should be analysed in respect to flexibility to respond to market needs.

# 4 Recruitment and entrance requirements

## 4.1 The entrance qualifications of the students in a strategic perspective

It became obvious to the review team that NTNU is proud to select students based on exceptionally good grades and the level of their mathematics and physics education in upper secondary school. We feel that the students enrolling at NTNU are rather homogeneous. Nonetheless the success rate in first year mathematics has recently been disappointing taking into account the background of the students. This problem will be addressed again later.

This kind of recruitment bears an inherent problem. At first the number of qualified young people leaving school is rather limited. As an increase in the number of graduates is desirable for the coming years, NTNU will need to address a widening of the recruitment basis to attract more motivated students. The argument, that it is better to reduce the number of students enrolled such that a ratio of applicants/student places of at least 1.5 or more than 2, is maintained as a measure to avoid a loss in quality of the students enrolled, is not supported by the review team.

Forcing young people to make such an important decision, limiting the fields of study available to them at 15-16 years of age is not common in other European nations, but seems to be a characteristic of the Norwegian and Swedish secondary and higher educational system. The extra limitation imposed by NTNU on the grade level achieved in secondary school mathematics, narrows the group of applicants even further, but has clearly given improved results in introductory mathematics in the past. It should be considered by NTNU if the necessary level of mathematical skills for a first-year student can be achieved also by introducing bridging courses to be passed successfully before final enrolment.

## 4.2 Recruitment from the upper secondary school and recruitment based on a Bachelor of Engineering Degree

The problem NTNU is facing regarding the recruitment situation is the same all over Europe. The actual job of an engineer is hardly known to most youngsters. In a media-driven society engineers play no significant role in TV series. Cooking competitions on TV, however, e.g. have significantly increased the number of applicants for the related training. A joint marketing initiative is necessary to improve this situation for engineering and the natural sciences. The review team has not looked into the marketing and recruitment activities of NTNU in any detail. Our comments on these issues, therefore, are limited to general observations.

In order to attract more female students, special recruiting programmes should be implemented to address girls between the age of 12 and 14. At a higher age, it seems to be increasingly difficult to convince girls to choose “non-traditional” fields of study. This is aggravated by the current application requirements to NTNU.

When providing programme information it must be easy to understand, guiding through the decision-making process and authentically as contact with today's students must give proof of the statements given on the web or in brochures. The names of some of the study programmes seem, for example, in some cases to be more guided by marketing needs than by the actual content of the programme. NTNU should assure that such internal competition between engineering programmes is limited, while maintaining a strong profile of the engineering profile of NTNU in general.

# 5 Structure of the MSc programmes

## 5.1 Consistency and progression of the topics within the programmes of study: "fade-in — fade- out"

According to the decisions taken by VK I and VK II all programmes are structured identically. The principal ideas followed by NTNU may be regarded as common practice. Nonetheless certain details lead to questions and comments in the following fields:

- the way the fundamentals are taught,
- the workload calculations,
- the flexibility to integrate new modules

As already mentioned above the success rate in mathematics does not really correspond to the nominal qualification of the students, although this has improved significantly after introducing a minimum secondary school mathematics grade to qualify for enrolment. During the interviews we got the impression that only limited effort is put into dedicating the mathematics lectures and exercises to the individual engineering programmes. An improved motivation and success rate could easily be achieved by addressing this deficiency.

A tightening of scales during the correction process of written examinations to (citation): "motivate students to struggle for better grades" (end citation) had been a didactical measure of the 19$^{th}$ century at primary or early years of secondary schools and should strictly be avoided in tertiary education.

With respect to the natural sciences service modules the percentage of practical laboratory exercises must not be reduced any further.

The suspicion that the equal ECTS size of modules does not reflect a realistic workload calculation was confirmed when checking for plausibility. E.g. it was stated that a rather limited workload necessary to pass the non-technological subject in the first half semester provides limited compensation for the extra workload needed to pass maths. Fig 1 of the supplementary report (page 25) is not helpful as it describes the average workload more or less over the whole of NTNU. It is highly recommended to install a monitoring process to evaluate the actual workload for the students.

The following figure provides an example of a German Bachelor's programme in mechanical engineering. This example follows the same fade in - fade out principle but accounts for the individual workload of the courses and provides a larger percentage of non-mandatory courses and thereby provides more flexibility with respect to:

- academic study tradition
- incorporation of new modules
- profile building within a programme

**Mechanical Engineering**

| ECTS | 1st semester winter | 2nd semester summer | 3rd semester winter | 4th semester summer | 5th semester winter | 6th semester summer |
|---|---|---|---|---|---|---|
| 1–5 | Analysis I for Engineers 8 LP | Analysis II for Engineers 8 LP | Measurement Technique & Data Analysis part 1 5 LP | Measurement Technique & Data Analysis part 2 5 LP | Practical work in industry part 1 6 LP | Practical work in industry part 1 6 LP |
| 6–8 | | | Construction IIa 10 LP | Fundamentals electable 6 LP | maschine design electable 6 LP | maschine design electable 6 LP |
| 9–13 | Linear Algebra for Engineers 6 LP | Construction I 6LP | | | | |
| 14–17 | Statics and elementary stability 9 LP | Kinematics and dynamics 9 LP | Introduction in IT 6 LP | Fundamentals electable 6 LP | free choice 6 LP | Bachelor Thesis |
| 18–21 | | | | maschine design electable 6 LP | free choice 6 LP | |
| 22–23 | | | Material Science part 2 3 LP | | | |
| 24–29 | Electrical Engineering 6 LP | Material Science part 1 3 LP<br>Manufacturing 6 LP | Fundamentals of fluid dynamics 6 LP | Project work 6 LP | Fundamentals electable 6 LP | free choice 6 LP |
| 30–32 | | | | | | |

Course structure for a German Bachelor's in Mechanical Engineering

Profile and flexibility are also discussed in the following sub-subjects.

## 5.2 Balance and flexibility between non-elective and elective topics

In addition to the reduced flexibility already discussed in the previous chapters we learned that the financial allocation system does not actually motivate to implement cross-structural programme elements. As most of the elective courses belong to this category the problem is addressed here. Money is allocated output driven per 60 ECTS units. This leads to keeping students “in house” or to force service providers to make offers at prices which are not fully covering the costs. One victim seems to be the management and economics education for engineers. This deficiency should be eliminated. Incentives should be installed in the financial allocation model to promote the hiring of expertise from other departments.

We have noted that 1000 courses, all nominally at 7.5 ECTS points, are offered. This very high number indicates considerable flexibility, but this is restricted by a rigid structure and the narrow definition of electives.

## 5.3 Multidisciplinary component of the educational programmes, and fraction and profile of non technological subjects

Modern engineering education requires a systematic education in what is called soft-skills. Industry underlined their needs to hire graduates trained in team working and interdisciplinary communication as well as equipped with competences in leadership and the ability to reflect their doing and responsibility to societal needs. The number of ECTS points included in the programmes fulfils international accreditation requirements.

The implementation however shows deficits. The first year (Ex.Phil.) course fulfils the scientific standards of the discipline but neglects the difference in clientele. Examples with an engineering perspective and of daily practice in industry are missing. In contrast to the needs of application oriented knowledge transfer the course principle is based on a generic scientific description losing the student due to the high degree of abstraction. A more service driven content is urgently needed, with a relevant problem-based approach.

The list of courses available as electives for the non-technological modules in later years should definitively express greater significance and relevance to the later engineering work fields in order to improve attractiveness and acceptance.

The report from the working group on “non-tech courses” provided in our background material shows awareness of these challenges. The review team supports the recommendations by this group, specifically:

- Changing the terminology from “non-tech” to “complementary courses”
- All complementary courses must be at an appropriate academic level
- Changing the content of Ex.Phil. to make it more relevant for engineering students (see above)
- Reducing the scope of the Technology Management course (C1), offering legal issues as an elective under Complimentary courses 2 and 3 (C2 and C3)
- Improving scope, content, and relevance of C2 and C3, with progression from one course to the next. Maintaining these as mandatory, but with the option to make C3 a technology elective
- Improving the engineering content and relevance of the Interdisciplinary Teamwork (EiT) course

## 5.4 Adaptability to alternative recruitment and horizontal mobility

One very special problem is to be addressed under this heading, which, however, is also relevant to the question of capacity. Currently NTNU offers three parallel programmes at master's level for one and the same subject. The first corresponds to the last 2 years of the integrated 5 year programme, the second to a master's course for students with a Norwegian BSc degree and the third is referred to as the international Master's programme taught in English and offered to foreign students. The review team recommends to close the Norwegian 2 year pro-

gramme and instead to open the international Master's programme to all non-NTNU Bachelor applicants for better efficiency.

# 6 Student mobility - nationally and internationally

The comment of the review team focuses on the international mobility as national is not so much in question due to the unique position of NTNU within Norway.

## 6.1 International mobility as the key element of the Bologna Process

The Bologna Declaration of 1999 has initiated the most far reaching reforms to European higher education in recent decades. The extent of the process refers to both the structural changes at European, national and institutional level and to the growing number of countries committed to creating a EHEA by 2010. Today, 46 countries are involved. The process aims at the harmonization of the structure of university education in order to facilitate quality assurance and mobility.

The main points of the Bologna Declaration are:

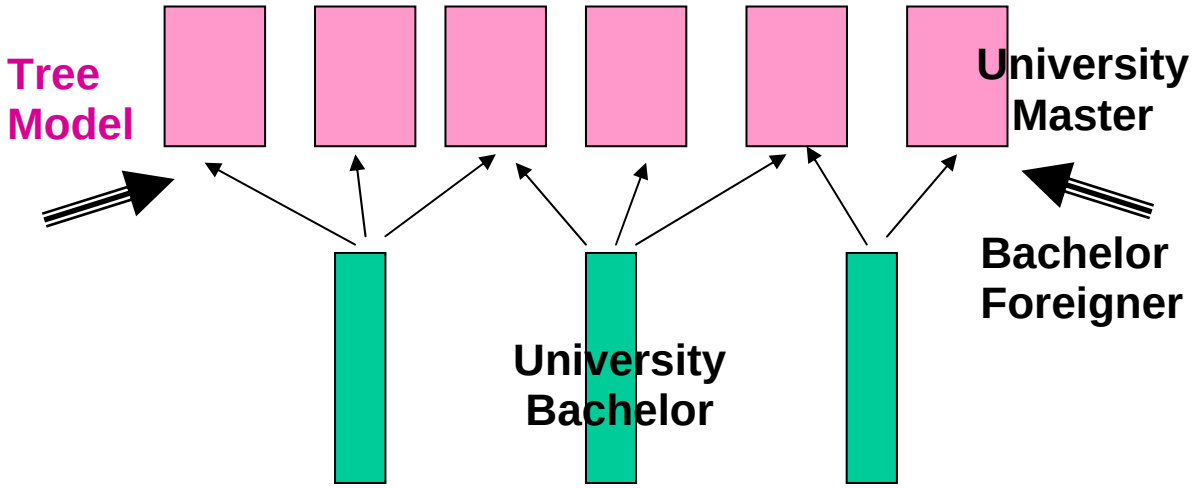
- adopt a system of easily readable and comparable degrees
- adopt a system with two main cycles[1]
- establish a system of credits
- establish a quality assurance system
- promote mobility
- promote European cooperation in quality assurance
- promote the European dimension in higher education

All these points have to be taken into account in the reform process of the higher education system and the specific curricula in different fields.

The motivation behind the Bologna Process, which started with the Sorbonne Declaration in 1998 and the Bologna Declaration in 1999, is two-fold:
On the one hand, the process aims at increasing student and staff mobility among European countries and creation of a common framework for the diverse European higher educational systems.

On the other hand, the process aims at increasing the attractiveness of Europe's universities to students from other regions of the world. Thus, the Bologna Process does not only represent a movement addressing the inner structures, but also aiming at students, scientists and researchers from all over the world, ensuring them that Europe remains an attractive place for their work. The enrolment to the Bachelor's programme as well as the change from the Bachelor's to the Master's education provide natural points of admittance of foreign students to the engineering education as such. A visualization can be seen in the next figure, showing the so-called tree structure.

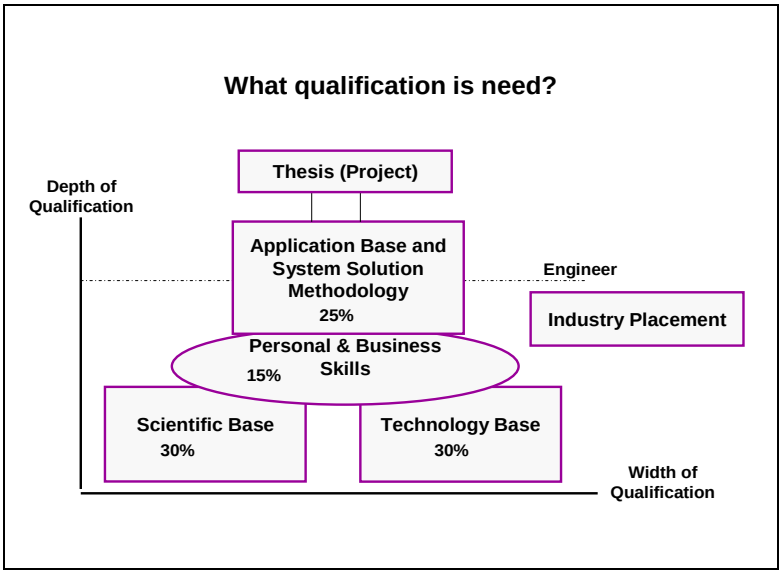
[1] The results of London conference allow interpreting the doctorate as the 1st experience of doing self-depending research and not as the 3rd cycle of education.




## 6.2 Possible transfer an integrated 5 year curriculum to the two cycle system

It was accepted by those countries mentioned as represented in the review team, that future engineering education should lead to employability after graduating from the first cycle. Nonetheless, it was also common understanding that an engineering education on the „Dipl.-Ing." level would still require the full five years.

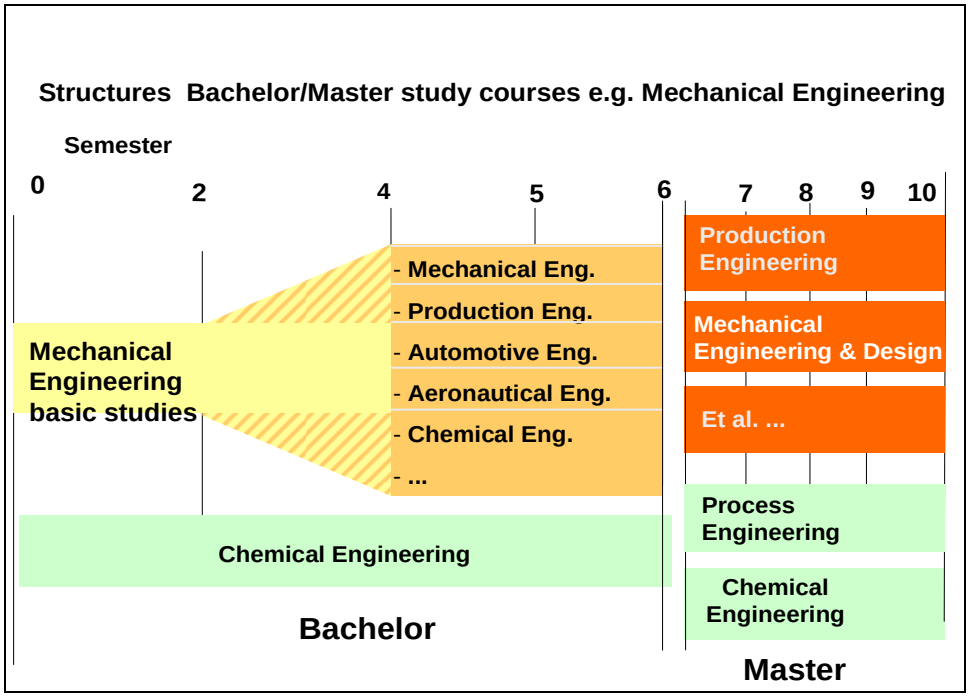
According to current standards of education a Master's graduate from a university is to have been educated to overcome existing boundaries of knowledge by the competence to perform independent research either during the third cycle of the Bologna Process, the PhD phase, or in industry. If one combines the research driven profile of a university, the necessity to develop the corresponding mirror image in education and the requirement of employability after the first cycle, the challenge becomes obvious. In a first step the profile for the complete 5 year programme was newly defined. Industry requests a sound education in engineering fundamentals and at the same time an up-to-date reflection of research results in the content, amended by soft-skills and intercultural competencies. Thorough discussion with numerous stake holders under the guidance of the German VDI (The Association of German Engineers) let to the following picture:



In a subsequent step the question of ensuring employability after the first cycle was treated. Employability can be defined as *adequately educated in fundamentals as well as practice, relevant methodologies to act independently in a professional environment within existing boundaries of knowledge and good practice*.

This is not a fully comprehensive definition, but it is sufficient to provide guidance in the spirit of Bologna. Based on this definition the task becomes transparent: enhance the amount of practice relevant methodologies in the first cycle, move the fundamentals of research relevance and very specialized character in the second cycle and integrate the soft-skill competencies already in the first cycle. Especially the last step may be regarded as hardly feasible because of the limited number of teaching hours per academic year. The problem can be solved by putting a paradigm shift into practice: from input to outcome determined education by modularization. These modules must contain more than traditional lectures. They need to address new ways of teaching like problem based learning and project work, which automatically integrate aspects of soft-skills.

The best way to develop such a new programmes is by starting at the final competence profile of the future graduate intended by the faculty and then to go backwards towards the scientific and technological routes in a kind of logical free structure. A result of such a process described in a generic manner is shown in the next figure.




Bachelor- and Master structure for Mechanical Engineering (adopted from Scholl; GVC - Gesellschaft Verfahrenstechnik und Chemieingenieurwesen)

Scientific and technological fundamentals are taught mainly during the first two years while specialization and system solution methodologies form the focus in the third year.

## 6.3 Accreditation as part of quality assurance

Wherever people meet, who are responsible for the design and the quality of curricula taught at institutions of higher education, the term mentioned most is “accreditation”. The trouble-

some point about it is that depending on their local origin, the experts talk about different processes and corresponding aims. In Norway they discuss system's accreditation, in Brussels they try to shape professional accreditation under the Bologna Process and in Washington they decide on the shaping of this procedure under the constraints of the related accord. And, as may be expected, the different procedures are not compatible!

Starting with the oldest activity of those three one has to look at the Washington Accord. Citation: "Established in 1989, the Washington Accord is a multinational, mutual recognition agreement of the substantial equivalency of the engineering accreditation systems of member signatories. The agreement recognizes the substantial equivalency of programs accredited by member signatories and recommends that the graduates of those accredited programs in any of the signatory jurisdictions be recognized by the other jurisdictions as having met the academic requirements for entry into the practice of engineering." In other words, it aims at the assessment of entrance qualification to a professional career. This procedure is outcome oriented and entirely based on program assessment.

EUR-ACE and Euro-Inf are European activities, funded by the European Commission and conducted under the aims of the Bologna Process. The standards and criteria applied are intended to provide a means for comparing higher education qualifications in the European Higher Education Area (EHEA), in a way that encourages the dissemination of good practice and a culture of continuous improvement of programmes. Accreditation of an informatics/engineering degree programme is the primary result of a process used to ensure the suitability of that programme as providing the education base for the entry route to professional practice." The conformity of the principal targets is obvious. Nonetheless, the fact that institutions of higher education in Europe, and there especially the universities, have a self-understanding as research driven institutes, trying to ensure doctorate skills for the third part of the Bologna Process, leads to the consequence that Bologna employability is not rated substantially equivalent to the requirements of the Washington Accord.

And finally: Norway. Here, institutes are accredited. This is a process, where the quality management process of the institution plays the governing role. This is no substitute for any of the other two approaches, as it does not address the quality and compatibility of the educational programme and content.

The prediction on the possible future development:
The European culture of engineering education should provide enough impetus to develop a European accord based on the activities mentioned above. And a fully established European Accord should be able to solve the existing problems of global mobility and negotiating on eye level mutual recognition with the Washington Accord.

## 6.4 Recommendations to NTNU

Within Norway there seems to exist a rather universal support for the integrated 5 year programme from different groups of interest, e.g. NTNU staff, student organizations and some of the review team members. Some review team members, mainly those from other European countries, look upon the problem from different perspective. Objectively both can provide a convincing rational for their position. In consequence the review team has decided to offer NTNU a number of pro and contra arguments. It is up to NTNU then to weigh them to be of more or less importance and to come up with a decision based on a critical discourse.

Arguments favouring retaining the 5 year integrated system:

- Due to the fairly short experience with the current model, it seems unreasonable to introduce a fundamental change of structure at this time.
- Discontinuing the five year programme now could be too disruptive, a waste of resources, and reduce the brand value of the NTNU engineering education. Resources may be better applied by discussing and implementing other recommendations given in this report.
- Fulfilling national expectations and requirements are regarded as being of greater importance socio-economically than international compatibility.

Arguments favouring a change to the Bologna system:

- NTNU may risk losing its position internationally and not reach its own strategic goals in 2020 if it does not open itself more to the European Area of Higher Education (EAHE).
- A stricter adherence to the Bologna 3+2 model would enhance international recognition and mobility. The points 2 and 5 to 7 of the seven points characterizing the Bologna process are incompatible with the current NTNU system.
- International cooperation on the joint degrees' level cannot be achieved without a strong identification with the Bologna Process.
- A change to the two cycle system should go hand in hand with volunteering for internationally valid programme accreditation procedures to offer NTNU graduates the security of international recognition of their degrees.
- A compromise for the NTNU could be the Swedish system. For the students it is still possible to be accepted to a full 5 year engineering programme. These programmes are however organized in a 3+2 year structure with either a mandatory or an optional BSc degree after the first 3 years.

The future development of engineering education in Europe should be followed closely by NTNU. If the harmonization efforts in Europe strengthen the case for a strict Bologna structure, NTNU should be prepared to adapt.

# 7 Learning quality, methods of learning

## 7.1 Infrastructure facilities (laboratories, library, ICT facilities etc)

In general, the facilities at the University are rated good to very good. Some installations are very modern and represent the current state of the art in science education. This is especially the case for equipment installed in recent buildings and laboratories. Some 4th and 5th year students have their own work facilities close to the experimental fields, which makes NTNU very attractive.

Criticism was mentioned related to the peak hours of examination periods. It was complained that during this time the number of study places become insufficient partially due to students from other, non-engineering faculties which during this period come to the engineering campus.

The review team, however, feels a bit uncomfortable about a different issue in that context: The team was not able to identify any kind of strategic plan for re-investment to ensure the timely upgrading of teaching material including hardware.

The same is true with respect to the absence of an e-learning strategy. We could not identify the extent of e-chalk use, the degree of integration of modern ICT tools in education, e.g. laptops. NTNU is recommended to work out related strategies urgently.

## 7.2 Internship

The Norwegian industry representatives we met stated that they are aware of their obligation to offer internships to the NTNU students. The students themselves regarded the current situation as satisfactory.

Internship can also be interpreted differently. People working in industry can be invited to contribute to the education of the NTNU students. This is already put into practice at NTNU but could be further elaborated upon. This way, students can be offered increasingly real-life problems from industry to solve during their studies. This will improve motivation, give them knowledge about potential future employers and tasks, and enable the students to hit the ground running when they enter working life. The industrial representatives signalled their interest to enlarge their contribution.

## 7.3 Student tutoring, guidance, study progression and drop outs

Student mentoring and tutoring is both performed at NTNU: on a voluntary basis by the student unions doing the mentoring and tutoring as part of the teaching concept to offer learning in small groups. The first is typical for the Scandinavian countries and may be regarded as best practice for other parts of Europe. The review team would like to emphasize that the recognition of the student union's contribution to the academic culture at NTNU should be significantly enhanced and find practical consequences in offering exceptions from the sometimes extremely inflexible rules for those active in that field.

The use of students in part time positions (tutors) to offer a learning environment of small groups was not assessed systematically by the review team. As no explicit criticism was put forward by students or teaching staff the team assumes that this part of the educational system is in good shape.

Guidance is given to the students up to an extent that the development of the person/personality as such is hardly challenged. Students should be taught to be more active and critical as learners, more reflecting and less consuming. At the moment they continue a school type kind of life! The review team recommends a change from student guiding to student coaching instead.

The current dropout rates are looked upon rather self-critically in the self-evaluation report. To some extent this is understandable if the entrance qualifications at NTNU are taken into account. Based on the entrance requirements one would not expect a tendency of rise in these figures over the years. A more or less constant average value of dropouts could be attributed to those students, who have acknowledged to have selected the wrong subject of study. In

any case these figures must not be compared to central Europe experience with less stringent entrance requirements. There dropout rates of approximately 50% are not uncommon.

The picture changes a bit when the tables are investigated a bit more closely. The dropout rates differ significantly from programme to programme and some have comparably high dropout rates. When asking for the most commonly mentioned reasons from the students or where they go when having left the programme no information was accessible to the team.

According to the team's perception one reason for drop out may be that the name (and advertising) does not fully reflect the content of a programme, something the students discover as soon as they are in the first year.

In any case it is highly recommended to get a follow-up system in place to be able to be responsive to own responsibilities causing these drop outs.

The examination regulations at NTNU appear as exceptionally stringent compared to those in place at the review team's institutions. It was not possible to identify the special need to have them in place as they are. At the institutions represented in the review team, students are often offered to choose if interim examinations are taken or not without consequences for the final examination. In the fundamental courses a system of 2 out of 3 successful examinations is frequently in place in order to pass the module. NTNU should discuss to make their system more flexible and thereby more student friendly.

## 7.4 Teaching methods

In general very conservative teaching methods are used. New approaches like project and problem based learning are recommended to be applied more frequently than currently in place. In addition the use of ICT in teaching and learning (experiments, simulations, examples, exercises…) should be developed and integrated. In a research-based education the amount of material to be taught rises exponentially over time while the time available to cover the curriculum almost remains a constant. This causes the need for didactical changes. According to the team's experience certain such changes could be fruitful and also motivating for the students. One has to keep in mind that the next generation of students are used to other learning methods than the current ones and have completely different experience with ICT in their daily life.

The didactical abilities of some teachers seem to be limited, at least from a student perspective. This is a common phenomenon in all our institutes of higher education and the awareness about it is rising. NTNU is recommended to introduce activities in the sense of teaching the teachers even more than it currently does. Everyone should be kept actively informed and involved in teaching improvements and introducing new teaching methods. This should be on the strategic agenda.

Teaching at a university should emphasize critical and independent thinking, and a desire and an ability to acquire knowledge, rather than being taught. This perspective should be applied when developing and evaluating teaching methods.

# 8 Organization and management of the engineering education

The review team wants to acknowledge that NTNU gives the organization and management of engineering education very high priority. The team has met numerous people who personally feel absolutely committed to the task to provide an up to date engineering education to the students. However, having said this it is also the task of the review team to point out areas of possible improvement.

In the beginning, when the team learned about the setup of the organization the situation appeared to be foggy and a bit overloaded with bureaucracy. So we tried to figure out how that organization is perceived at the different levels of operation. Pretty quickly it became obvious that the members of FUS know exactly what they are supposed to do. On the other hand, at the lecturer's level FUS and its tasks became fuzzy. Especially the question of who just gives advice and who actually makes decisions is not clear to all. Although the documents state exactly the tasks and responsibilities of the individual committees the practical action may differ from time to time.

The review team believes to have identified overlapping roles executed by and between faculties, department boards and programme councils. Open questions seem to be: who is finally responsible for the total programme, the overall learning outcomes, the course assessments, the follow ups, etc. The money for teaching goes from the faculties to the departments, while the responsibility for the programme content and management is (or should be) handled by the FUS and the programme councils. But since the money goes to the departments they generally seem to adopt also the responsibility, making the roles of the programme councils very unclear. Programmes which are closely linked to only one department seem to run more smoothly than programmes which include courses from several departments or, even worse, those who are run over faculty boarders.

As a result of the interviews the team recommends the following for internal reflection:

- Whenever the board of the university discusses educational problems it should make this transparent to the rest of the university. The fact that they care for education should become more visible!
- FUS should concentrate its activities more on strategic issues instead of dealing with details and this way eliminate the impression of conducting "micro management"
- Those issues, which let FUS give the impression of conducting "micro management" should be delegated to the Programme Committees as far as possible. The Program Committee should be responsible for the quality of the courses and the structure. The Heads of Programmes should have a mandate to change teacher/ teaching methods.
- The responsibilities for inter-faculty programmes should be clearly defined. Here, there seems to exist an empty space

In the same context certain remarks are now made with respect to the quality management system at NTNU. The description provided to the team reads very convincing. But additional work is still necessary to make it a system integrated in everybody's activities. Quality Assurance appears to be seen as way to handle serious exceptions and deviations, rather than a tool for continuous improvement of teaching quality. The KVASS system does not seem to be accepted or used by the departments, programme councils or teaching staff. To the team's surprise we did find out that the programme councils, which should be responsible for the

programme do not get access to the students' course evaluations. The students' opinion or assessment is very important. Therefore the team regards it as surprising to have learned that the management of a programme does not know inherently if a course is working well or not.

Collecting the course feedback should not be the responsibility of students but the programme committees. Students should be given a uniform means to give anonymous feedback on every course they take during their studies. At some of the team members' universities web-based assessment forms are used for all courses and at all faculties. This gives the possibility to compare the overall satisfaction with different programmes. Some questions are included on behalf of the rector or vice-rector in charge of education, others are defined by faculties, programme councils and also the individual course teacher can include questions. This way the feedback is quite comprehensive and provides good guidance, e.g. on the acceptance of newly introduced project based or problem based learning courses. Special acknowledgement for splendid teaching efforts can be given. This is very appreciated by the teachers. In Sweden and Germany these results are also used in salary revisions.

If adopted at NTNU the Programme Committees could and should provide an annual quality report that is standardized among the engineering programmes. Follow up activities should be clearly pointed out in their report.

Finally a brief comment will be made with respect to the strategic planning and the targets defined for 2020. It may be a non-representative observation made by the team, but to the team's perception the targets and their motivation are not well communicated. As pointed out in Section 2.2, this lack of strategic alignment will give obvious management challenges. To improve this situation, incentives should be linked to the strategic goals at the lower level of organization. The benchmarks which are regarded as crucial and with whom NTNU seeks comparative assessment should be made more public.

## *APPENDIX*

A) Comments concerning the programmes and the self-evaluation work
B) The mandate of the review team
C) The review visit programme
D) The curriculum vitae of the review team

# A) Comments concerning the programmes and the self-evaluation work

The comments given are provided on the basis of the self-evaluation reports, the meetings with faculty management and teachers as well as the meetings with students. It should be noted that our dialogue with the faculty and programme management had to remain restricted to a limited number of programmes, and the review team did not perform an in-depth evaluation of all self-evaluation reports.

*General comments concerning the self-evaluation process*
The review team acknowledges the efforts by NTNU to conduct the self-evaluation work and prepare the reports for all the MSc engineering programmes. The approach, demanding the definition of the programme learning outcomes and the mapping of all mandatory courses in order to achieve the programme goals as well as the SWOT analysis exercise, has been well selected to provide important input for a continuous development and improvement of the programmes.

However, there is room for improvement in the process. The quality of the reports and the way the self-evaluations reports were produced varied considerably from programme to programme. Examples of this variety are the composition of working groups, the size of the working groups and way the work was conducted. Also the interpretation of the protocol used differed. This becomes obvious when comparing the matrices for the different programmes. In most cases the review team was not able to see a clear link between learning outcomes and the individual courses. Here, the matrices only provide good answers in limited cases. Furthermore, in many reports “opportunities” are not linked to “strengths” and/or “stakeholders/ drivers” of the outside world. Some statements have been perceived by the team as representing rather wishful thinking.

Many of those involved in the self-evaluation work stated to the team that the work had been much too time consuming and not in satisfactory balance with the output. The review team would recommend that the next round of self-evaluation reports should be based on clearer instructions, especially regarding the assignment of clear responsibilities for the individual tasks. The definition of terms and parameters should be clearer. Conducting more introductory workshops and allowing for more intense discussions on the interpretation of the exit qualifications, for example, should also be considered.

Concerning the NTNU vision, it is clear that the vision is known, but not widely accepted or acknowledged. One comment is also that the vision is coupled more to research than to education.

## Programmes in the IME faculty

Many of the programmes in the IME faculty overlap and have many courses, profiles and specializations in common. The reason, why there is not one programme with different profiles only, seems to be marketing driven to attract more students.

**Energy and the Environment Engineering programme**
This merger of the Power Engineering and the Mechanical Engineering programmes was introduced in 1998. It accepts more than 100 new students per year and is the programme within the faculty with the largest percentage of female students, 40%. A closer look reveals

that the major emphasis of the programme lies on energy engineering rather than on environmental issues. For example, there are no courses on waste treatment and management or environmental management. In the opinion of the review team it is not sufficient to claim that working with energy provides sufficient links to environmental issues. The team therefore recommends that the programme is amended by true environmental courses.

**Electronics programme**
The offers many specializations and most courses are given by the Department of Electronics and Telecommunications. This is a large department with extensive and successful research. Even so, the question arises if it is financially wise to offer so many specializations. Is it a requirement from industry or is it in the interest of the professors to offer courses within their area of specialization?

**Communication Technology programme**
The Communication Technology programme offers many specializations. In relation to the number of students accepted per year, 50 in 2007, a reduction from 8 to 7 specializations might not be enough.

**Engineering Cybernetics programme**
Like the Electronics programme, the Engineering Cybernetics programme has the smallest percentage of female students. The review team has not been able to identify any new ideas as how to increase the female interest in these programmes. However, one interesting effort has been made in the past by offering a special computer room for female students to make the female students in a programme feel more comfortable. This seems to have been very much appreciated.

The Electronics programme has the largest drop-out rate within the faculty. There was no information available to the team, if the female students drop out or change programmes to a larger extent than the male students.

Furthermore, the review team was quite surprised by the self evaluation of the Engineering Cybernetics programme and the very negative attitude of those responsible for performing the work according to the chosen protocol. To have one department, or programme council, refusing to adapt to a model chosen by the NTNU management might be troublesome, internally when asking for resources without proper justification in the self-evaluation report, or externally when seeking international accreditation.

Contrary to Engineering Cybernetics, the Communication Technology programme had previously worked with outcome qualifications and had found the work useful. Also the Electronics programme acknowledged that some useful results had come out of this work, but pointed out that the protocol might need some adjustment.

**Computer Science programme**
The Computer Science programme was in favour of mapping the outcome qualifications for the whole programme, but stated that there was a problem since most teachers are more interested in their own courses and ”do not feel ownership of the whole matrix”.

The Electronics programme (it is unclear if it was the programme council or the department) has performed an industry survey which of course is very interesting regarding a reflection of the programme's learning outcomes and exit qualifications. Some other programmes, e.g. Computer Science, have had surveys done, too. Unfortunately, no correlation between the

surveys seems to be present. A common part of the surveys, of course, would have made it possible, to undertake interesting comparisons.

## Programmes in the NT faculty

The NT faculty hosts 4 MSc in engineering programmes. The faculty is also responsible for BSc and MSc programmes in the natural sciences running according the Bologna 3+2 system. Even so, there is little support or discussion among the teachers to adapt the 3+2 structure also for the engineering programmes. Only the Department of Chemical Engineering regards this as plausible.

The faculty has extensive research activities and there was a discussion concerning the risk that in consequence research rather than education is the main concern of the faculty, professors and teachers. Incentives for good teaching and commitment in educational work are urgently required or to be made more visible here. This is a critical issue.

The review team confirms the statements of their colleagues at NTNU that there exists a problem with old laboratory equipment and the need for new, sometimes very expensive, equipment.

Laboratory supervision for students is most often performed by PhD students. As the majority of PhD students nowadays are coming from abroad, a language problem arises. This is a serious problem that must be addressed, especially when considering the necessity that the students must fully understand the safety regulations

### Applied Physics and Mathematics programme

This is the only engineering programme of its kind in Norway. Considering the success of these students in the mathematics courses it is clear that the programme attracts good students. The quality of students is of great concern for the programme management. They are very reluctant to accept more students even though that would result in increased income. The students have a track record of high quality in their subjects. However, management should put emphasis on integrating more communication skills as well as social skills.

### Chemical Engineering and Biotechnology programme

This is the programme which attracts the largest number of female students at NTNU. The drop-out rate is on the average NTNU level, but it would be interesting to learn how gender and drop out correlate.

The programme has its roots within the NT faculty but consists of courses from several departments. This should not be a drawback for the students. But it is important that the programme council takes responsibility and creates an efficient cooperation between the different departments that run the courses in parallel during the semesters. Perhaps fewer departments would be one way of reducing the problem.

The review team learned that the courses in pulp and paper only attract 3-5 students per year. The reason for still offering these courses is the “responsibility towards Norwegian pulp and paper industry”. This is honourable, but is it financially sensible?

Another question concerning the Chemical Engineering and Biotechnology programme is why the interaction with medicine is so small. Hopefully, it is not the budget model that prevents cooperation.

**Materials Science and Engineering programme**
This is one of the smaller programmes at NTNU accepting 30 students per year. Even so the programme lists 6 different specializations. (This number will be reduced 2008.) Recruitment and keeping the accepted students is, and must be, considered a main concern for the programme.

**Nanotechnology programme**
The Nanotechnology programme also accepts 30 students per year only, but attracts 10 times as many primary applicants, making it the most attractive programme at NTNU. It remains to be seen if the graduates also will top the list of what Norwegian industry wants.

The review team has thoroughly taken into account all statements received during the stay at NTNU. Nonetheless the team unanimously has come to the conclusion to recommend a merger of these last two programmes, Materials Science and Engineering and Nanotechnology, into a common Materials Science and Nanotechnology programme.

## Programmes in the IVT faculty

The Faculty for Engineering Science and Technology (IVT) hosts seven programmes for an MSc in engineering. They range from the largest (civil and environmental) to the smallest (product design) programme, and include areas of particular importance for the Norwegian economy, like petroleum engineering and marine technology.

**Civil and Environmental Engineering Programme**
Civil and environmental engineering seems a well-structured programme. It has good facilities, which are also used to give students an early introduction to the practical aspects of the field. This approach may be worth emulating by other programmes. The department has good connections to the Norwegian construction industry, and has set up an industry ring as a way to formalize this interface. Both private and public employers see a need for an increased number of qualified graduates, but only a limited number of candidates are admitted. This discrepancy is evident in other fields as well, and should be addressed by NTNU at the political level.

The SWOT analysis of the Civil and Environmental Engineering Programme in our view over-emphasizes the “lack of resources”. A SWOT analysis should be used to identify opportunities and threats as a tool to manage change, not as an expression of general discontent.

Programme management pointed out that the budget model limits flexibility across faculties, as the use of resources at other faculties may lead to a “loss of ECTS points” in the model. Applying the model less rigorously may be a solution, but basic model changes that stimulate inter-faculty trade of services seem preferable.

**Marine Technology programme**
The Marine Technology programme has an equally strong in its link to the industrial sector. Their access to large-scale testing facilities is attractive to both students and researchers, and some interesting examples were shown of their use in providing hands-on experience to students. This seemed to contrast with the fairly conservative responses given when the teaching staff were asked about teaching methods.

**Earth Sciences and Petroleum Engineering programme**
The MSc in Earth Sciences and Petroleum Engineering has recently been split in two programmes, generating a new programme for Geology. The tendency towards an ever-

increasing number of MSc Programmes has been addressed in the main report. In this case the intent seems to be to recruit students directly into geology, to secure sufficient candidates later on. The review team remains sceptical towards such early specialization.

In their self-evaluation report, the group points out that the rigid structure drives the NTNU engineering programmes towards a generalist rather than a specialist profile. They may have a point, but reducing the time allocated to complementary courses is not a remedy we support.

**Product Design Engineering**
Two confusingly similar programme names, Product Design Engineering and Product Design and Manufacturing, in fact describe two very different programmes. The first is an industrial design study, giving students a mix of engineering, practical and aesthetic training. The programme is very popular, with one of the highest admission qualification requirements, and candidates have been much in demand by Norwegian industry. Again, the availability of qualified students combined with a societal need would seem to indicate a need for a higher level of student admissions.

The Product Design Engineering self-evaluation report contains a systematic evaluation of each cluster of courses against the defined learning objective, a useful approach. It also discusses teaching methods in more detail than most of these reports, a likely indication that the emphasis on teaching is high.

Their report also explicitly discusses the Bologna accreditation dilemma faced by NTNU, and points to some useful scenarios that may be useful in following up this challenge as recommended in our main report.

**Product Design and Manufacturing**
Product Design and Manufacturing is largely a classical mechanical engineering programme with a new name, seemingly to make it more attractive. With 140 students it is a large programme, serving a wide range of industries. The drop-out rate (about 30%) is reasonably seen as a challenge, but it remains unclear whether the proposed actions will be able to reduce this number. The group also follows NTNU's general tenet that fewer than 2.5 primary applicants per student place is a problem, which is a view that is not necessarily shared by the review team.

**Engineering and ICT programme**
Our team did not meet the programme management for Engineering and ICT, a programme established as recently as 2002. Whether the application of ICT in different fields of engineering warrants a special programme, or should be incorporated as electives in the other programmes, is therefore still an open question to us. Offering ten “main profiles” in a programme with only 50 students per year also seems excessive, and is described as a weakness in their SWOT. The programme was subject to external evaluation in 2006, a report which this review team has not studied.

**Industrial Economics and Technology Management programme**
This programme is unique at NTNU, in that it combines several disciplines and is managed by a “non-engineering” faculty. The staff comes across as having high self-esteem, providing a balanced self-assessment with a conscious effort to make this review valuable. They were the only group to point out that this process had given them new ideas about teaching methods, and the only ones who had invited outside peers to look at their review documents. IØT may be a good place for other faculties to look for “best practice” when another round of self-

assessment is considered. The skills and resources of IØT should also be considered by NTNU in development of university management models, interdisciplinary work, etc.

IØT appears as more outward looking than other departments. They are very actively engaged in international collaboration and see this as an important aspect of their programme. They also have a strong programme and attention to stimulate innovation and entrepreneurship. We did not, however, go into detail in these areas.

The staff seems to be active in exploring new teaching methods. In light of the highly select group of students, it was surprising to learn that even this programme finds students who "expect to be taught", require everything to be lectured, and are difficult to engage in discussion and independent thinking. This seems to be a general challenge at NTNU and should be addressed as such. The experience in industrial design, where the opposite claim is made, may be a useful reference.

## Meetings with students

The students are generally very proud of the education programme they attend, but they can also see space for improvement.

The students underline that problems existing in the management for those enrolled in cross-departmental or cross-faculty programmes. They experience "no one cares for you" and "a lack of coordination". For students attending programmes that are linked closely to one department experience many benefits. They are well taken care of by the department and the teachers of the different courses communicate well. The programme councils need to address this problem.

We were given evidence of another problem: the lack of responsibility to care for international students. The student association takes an appreciated responsibility to introduce the Norwegian students to NTNU and their studies, But what about the international students? Also the information to NTNU students about international possibilities could be improved.

# B) The mandate of the review team

Letter of appointment from Rector Torbjørn Digernes
NTNU, 20 December 2007

## Evaluation of the Master of Science in Engineering at NTNU

We greatly appreciate that you have accepted to take part in our quality improvement efforts and provide your judgement and advice on the further development of our Master of Science in Engineering Programme (MSc).

We have completed the first stage of the evaluation process, and have sent our self-evaluation report to the review team today. The self-evaluation includes reports on each individual MSc in Engineering Programme and an overall report where we have identified generic issues. To understand the engineering education model of our university, we also provide the review team with the reports from the Curriculum Development Committee whose work has largely determined the current structure of our engineering education programmes (Engineering Education in the 21st Century, 1993) and their non-technology components (2003).

In the external evaluation phase, we anticipate that in addition to the self-evaluation reports and key documents, the review team will base their evaluation on interviews with key stakeholders and general information obtained by the committee during the pre-review and review visits at NTNU. We also appreciate external observations, recommendations and reference to best practice based on the general competence of the review team.

**Objective and key issues**
The objective of the evaluation of the MSc in Engineering Programme at NTNU is to evaluate core issues of the programmes of study as a basis for further development. An overall aim is to consider the relationships between the teaching activities and design of these programmes, their basis in R&D activities and societal role. The evaluation should emphasize various quality aspects of the programmes of study such as structure of the programmes, programme content, level and progression, organization and governance of these master's programmes.

The objective of the evaluation can be summarized in four simplified questions:
- Do we have a portfolio of programmes of study that is needed to meet the needs of society?
- Is the MSc Engineering Programme structure sufficiently flexible to accommodate the learning objectives of the programmes of study?
- Is the MSc Engineering Programme structure suitable for international cooperation and mobility?
- What is the overall evaluation of the quality of the MSc Engineering Programme and how can it be improved?

We anticipate that the external evaluation will address the six key issues below. To provide some further guidance, we have in bullet points indicated some of the most relevant themes and problem areas from the point of view of the Executive Committee of the Engineering Education (FUS).

1) *Relevance of the MSc Engineering Programme to the needs of the society*:
   - Balance of educational activities supporting development of knowledge, skills and general competences.
   - Number of programmes of study within the MSc in Engineering degree at NTNU, including comprehensiveness and contents of the programmes.
   - Capacity of the MSc Engineering Programme in total and for the various programmes of study.

2) *Recruitment and entrance requirements*:
   - The entrance qualifications of the students in a strategic perspective.
   - Recruitment from the upper secondary school and/or recruitment based on a Bachelor of Engineering Degree.

*3) Structure of the MSc programmes*
   - Consistency and progression of the topics within the programmes of study: "fade-in – fade-out".
   - Majors and main profiles within the various programmes of study.
   - Balance and flexibility between non-elective and elective topics.
   - Balance between basic and applied topics, comprehensiveness versus specialization of the programmes.
   - Multidisciplinary component of the educational programmes, and fraction and profile of non-technological subjects.
   - Adaptability to alternative recruitment and horizontal mobility.

*4) Student mobility – nationally and internationally*
   - Structure of the 5-year integrated MSc in Engineering Programme at NTNU (300 ECTS) as a basis for vertical (student transfer) and horizontal (student exchange) student mobility, nationally and internationally.

*5) Learning quality, methods of learning:*
   - infrastructure facilities (laboratories, library, ICT facilities etc)
   - internship
   - Competence of staff related to the profile of the programmes and relevance to research topics
   - Student tutoring, guidance, study progression and drop-outs
   - Staff involvement in national and international education/research institutions.
   - Competence of the students graduating in relation to the intended learning outcome.

*6) Organization and management of the engineering education*

**The international review team – roles and responsibilities**
The international review team is composed of eight representatives from European technological universities and Norwegian industry:

- Professor dr. ir. Peter A. Wieringa, Director of Education TU Delft
- Professor Helen Dannetun, Dean Linköpings tekniska högskola
- Professor Helge Elbrønd Jensen, Danmarks tekniske universitet
- Professor Jorg Steinbach, 1st Vice-President TU Berlin
- Fagdirektør Terje Olav Moen, TEKNA
- Divisjonsdirektør Berit Svendsen, Telenor
- Siv.ing. Knut Harg
- Sara Eriksson, student KTH
- Elli Pyykkö, student TKK

The review team members will be responsible for:

- studying the self-evaluation material, preparing for the evaluation visits,
- taking active part in the evaluation meetings, asking probing questions,
- debating issues arising with fellow committee members, agreeing collective conclusions, planning the external evaluation report and contributing to draft sections of the report on agreement with the committee.

The lead evaluator will in addition to the tasks of the team, be responsible for:

- delivering the evaluation report to NTNU which includes: determining the structure of the report, allocating drafting responsibilities and signing off the final draft.
- in advance of the review visit, taking the lead in identifying the issues to be addressed by the evaluation committee, in consultation with the leader of the Executive Committee for Engineering Education at NTNU (FUS).

The NTNU secretariat will be responsible for:

- planning and organizing the meetings and review visits in liaison with the lead evaluator,
- coordinating and providing editorial assistance to the lead evaluator preparing the evaluation report,
- providing background information and additional information from NTNU upon request by the review team.

The university offers a fee of:

- NOK 30 000 for the team members with a management position (about 3700 euro),
- NOK 15 000 for student team members (about 1850 euro) and
- NOK 50 000 for the lead evaluator (about 6 300 euro).

We will in addition cover direct expenses against receipts. These are expenses such as travel, accommodation and other similar expenses. Practical information in this regard will be given during the pre-visit.

**The time frame for 2008**

| Time | Activity |
|---|---|
| End-January | Self-evaluation report sent to the review team by mail and core parts by email. |
| 18-19 February | Pre-visit - First evening: getting to know each other<br>Pre-visit - Second day:<br>• develop an understanding of MSc engineering education at NTNU,<br>• clarify the mandate of the review team and key issues to be addressed,<br>• plan the review visit identifying key issues and stakeholders. |
| 14-18 April | Review visit to:<br>• discuss key issues with internal and external stakeholders and visit some facilities,<br>• informally sum up observations, identifying major issues from the review visit, advance recommendations and examples of good practise<br>• prepare evaluation report process- dividing tasks and setting deadlines.<br>• give an oral report on preliminary observations and recommendations to the Committee for Engineering Education at NTNU (FUS)<br><br>First evening – internal planning<br>Second day – review meetings<br>Third day – review meetings<br>Fourth day – review meetings<br>Fifth day – internal work and oral report to FUS |
| 9 June | Review team meeting to discuss first draft of evaluation report<br><br>One day meeting (in Copenhagen) |
| 11 July | Draft report sent to NTNU for factual comments. |
| 15 September | Final updates by secretariat under the guidance of lead evaluator.<br>Final report delivered to NTNU. |

Once again, we express our appreciation that you will take on this task and support us in our further development.

Yours sincerely,

Torbjørn Digernes
Rector

Bjørn Torger Stokke
Dean of Engineering Education

Enclosure:
Contact information – review team members

## C) The review visit programme

**Evaluation of the MSc in Engineering Education at NTNU - Programme for the review week**

| Monday 14 April | Tuesday 15 April | Wednesday 16 April | | Thursday 17 April | | Friday 18 April |
|---|---|---|---|---|---|---|
| | **0900-1130 FUS** | **0900-1130 IME Management** FUS Dean, Dept.Heads, Programme Chairs | **0900-1130 IVT Management** FUS Dean, Dept.Heads, Programme Chairs | **0900-1130 NT Management** FUS Dean, Dept.Heads, Programme Chairs | **0900-1030 IØT Management** Dean, FUS Dean, Dept.Head Programme Chair | **Internal work** Review team |
| | **1130-1200 lunch** | **1130-1200 lunch** | **1130-1200 lunch** | **1130-1200 lunch** | **1030-1230 Staff involved** in: *- ind. econ.tech.man.* *- non-tech 2* | |
| | **1200-1400 Non-tech compo-nent** | **1200-1400 Staff involved** in: *- Energy Environ.* *- Electronics* | **1200-1400 Staff involved** in: *- Civil Eng* *- Marine* | **1200-1400 Staff involved** in: *- Chem. Biotech* *- Materials* | **1230-1300 lunch** | |
| | **1400-1600 Industry perspec-tive** | **1400-1500 IME** infrastructure (site visit) | **1400-1500 IVT** infrastructure (site visit) | **1400-1500 NT** infrastructure (site visit) | **1300-1500 Innovation** - education, students, infrastructure | **1330-1530 Oral Report** ProRector, Deans, FUS |
| **Student perspective** FUS stu-dents | **1600-1800 Intern. mobility** (Bologna) Rector, ProRector, Deans | **1500-1700 IME/NT** students from selected pro-grammes | **1500-1700 IVT/IØT** students from selected pro-grammes | **1500-1700 Basic subjects – special focus on mathematics** | | |
| **1800-2100 Internal work** | **1800-2100 Internal work** Review team | **1800-2100 Internal work** Review team | | **1800-2100 Internal work** Review team | | |

| **Mandate (main issues)** |
|---|
| 1. Relevance to the needs of society |
| 2. Recruitment and entrance requirements |
| 3. Structure of the MSc programmes |
| 4. Student mobility - nationally and internationally |
| 5. Learning quality, methods of learning |
| 6. Organization and management |

## Practical information

**Members of the international review team**

**Group I (IME, NT):**

- Professor Jorg Steinbach, 1st Vice-President TU Berlin (lead evaluator)
- Professor Helen Dannetun, Dean Linköpings tekniska högskola (group leader Wednesday)
- Fagdirektør Terje Olav Moen, TEKNA
- Siv.ing. Bjørn Sandnes represents Divisjonsdirektør Berit Svendsen, Telenor
- Sara Eriksson, student KTH

**Group II (IVT, IØT):**

- Professor dr. ir. Peter A. Wieringa, Director of Education TU Delft (group leader)
- Professor Helge Elbrønd Jensen, Dean of Education DTU
- Siv.ing. Knut Harg
- Elli Pyykkö, student TKK

**The self-evaluation reports made by FUS and the 16 Programmes of Study are available on this website:**

http://www.ntnu.no/omntnu/evaluering/siving_2008

| **Tuesday 15 April 2008 – meeting with FUS, industry, thematic meetings on international mobility and non-technological component** | | | |
|---|---|---|---|
| **Time and place** | **Purpose** | **Participants** | **Comments** |
| 0900 -1130<br>NTNU Hovedbygget<br>Møterom 201 all day<br>(2nd floor, Westwing) | **FUS** | Bjørn Torger Stokke (Chair)<br>Anne Borg, NT<br>Kristian Seip, IME<br>Olav Fagerlid, IØT<br>Svein Remseth, IVT<br>Øyvind Aas, student<br>Ane Christophersen, student | |
| 1130-1200 | **Review team lunch** | Review team | |
| 1200-1400 | **Non-tech component** | Anne Borg, FUS, Non-techn. working group<br>Bojana Gajic, Programme Chair Electronics<br>Kjell Wiik, Programme Chair Chemical Engineering/Biotechn.<br>Øyvind Aas, FUS student<br>Tim Torvatn, Coordinator Technology management 1, IØT<br>Brit Strandhagen, Coordinator Ex.phil., HF | |
| 1400-1600 | **Industry perspective** | Carla A.M. Botten-Verboven, Federation of Norwegian Industries<br>Gaute Myklebust, Atmel Norway AS (ICT)<br>Terje Norddal, Rambøll (Civil Engineering industry ring, NTNU)<br>Morten Rønnekleiv, StatoilHydro (Petroleum)<br>Odd Arne Lorentsen, Hydro Aluminium<br>Bjørn Dagfinn Pedersen (Marine industry) | |
| 1600-1800<br>(Pizza-dinner in meeting room) | **International mobility - Bologna model** | Torbjørn Digernes, Rector<br>Julie Feilberg, Pro-Rector<br>Bjørn Hafskjold, Dean, NT<br>Ingvald Strømmen, Dean IVT<br>Jostein Grepstad, Vice Dean Research IME<br>Olav Fagerlid, Vice Dean SVT<br>Bjørn Torger Stokke, FUS Chair | |
| 1900 Britannia<br>Meeting room | **Review team meeting** | Review team, Kristin | |

| **Wednesday 16 April 2008 – Group I – programmes of study at IME – management, staff, students and infrastructure** | | | |
|---|---|---|---|
| **Time and place** | **Purpose** | **Participants** | **Comments** |
| 0900 -1130<br>IME<br>Elektrobygget<br>Rådsrom all day<br>(G-114) | **IME management** | Kristian Seip, Vice Dean (FUS)<br>Tor Onshus, Progr.Chair Eng. Cybernetics<br>John Krogstie, Progr. Chair Computer Science<br>Bojana Gajic, Progr. Chair Electronics<br>Ivar Wangensteen, Progr. Chair Energy and Environment<br>Bjarne E. Helvik, Vice Progr. Chair Communication Technology<br>Kjell Bratbergsengen, Dept. Head Computer and Information Science<br>Idar Hansen, Vice Dept. Head Mathematical Sciences<br>Ragnar Hergum, Dept. Head Electronics and Telecommunications | |
| 1130-1200 | **Review team lunch** | Review team, Vice Dean | |
| 1200-1400<br>IME | **Staff involved** in:<br>- *Energy Environ.*<br>- *Electronics* | Professor Ivar Wangensteen, Electric Power Engineering<br>Senioringeniør Halsten Aastebøl, Electric Power Engineering<br>Assoc.Prof. Kjell Erik Rian, Energy and Process Engineering<br>Assoc.Prof. Bojana Gajic, Speech Processing<br>Assoc.Prof. Lars Lundheim, Signal Processing in Radio Communications<br>Prof. Trond Ytterdal, Microelectronics, Analog and Mixed Circuit Design<br>Prof. Jostein Grepstad, Electronic material technology<br>Prof. Ulf Kristiansen, Numerical Acoustics<br>Research fellow Sigrid Berg, Phd-student (Teaching Assistant) | |
| 1400-1500<br>IME | **IME infrastructure (site visit)** | Halsten Aastebøl (guide)<br>Auraliseringslab - acustics (Peter Svensson)<br>Antenne lab – radio systems (Terje Mathiesen)<br>Laboratory renewable energy and electrical machines (H.Aastebøl)<br>High voltage laboratory (Frank Mauseth) | |
| 1500-1700<br>IME | **IME/NT students** | Trond Blesvik, Electronics<br>Maren Leithe, Engineering Cybernetics<br>Hege Grøstad Thalberg, Industrial Mathematics<br>Morten Beinset, Chemical Engineering and biotechnology<br>Carl Huse, Nanotechnology<br>Tor Johansen, Materials Science and Engineering | |
| 1700 Hangaren | **Review team dinner** | Review team, Kristin | |

| **Wednesday 16 April 2008 – Group II - programmes of study at IVT – management, staff, students and infrastructure** | | | |
|---|---|---|---|
| **Time and place** | **Purpose** | **Participants** | **Comments** |
| 0900 -1130<br>Høgskoleringen 6<br>IVT<br>Meetingroom 268<br>all day | **IVT Programme management** | Svein Remseth, Vice Dean Education (FUS)<br>Hilde Lysne, head of administrative section education<br>Eivind Bratteland, Programme Chair, Civil and Environmental Engineering<br>Bernt J. Leira, Programme Chair, Marine Technology<br>Tor Ytrehus, repr. Programme for Product Design and Manufacturing<br>André Liem, Programme Chair, Product Design Engineering<br>Sverre Ola Johnsen, Programme Chair, Earth Sciences and Petroleum Engineering<br>Ole Ivar Sivertsen, Programme Chair, Engineering and ICT<br>Helge Brattebø, Dept. Head Hydrolic and Environmental Engineering<br>Lars Sætran, Deputy Dept. Head Energy and Process Engineering | |
| 1130-1200 | **Review team lunch** | Review team, staff and Vice Dean IVT | |
| 1200-1400<br>IVT | **Staff involved** in:<br>- *Civil Eng.*<br>- *Marine* | Professor Steinar Nordal, Dept. of Civil and Transport Engineering<br>Professor Nils Reidar Bø Olsen, Dept. of Hydrolic and Environmental Eng.<br>Professor Karl Vincent Høiseth, Dept. of Structural Engineering<br>Professor Arild Holm Clausen, Dept.of Structural Engineering<br>Research-fellow student Linn Grepstad, Dept. for Structural Engineering<br>Professor Carl Martin Larsen, Dept. of Marine Technology<br>Ass. Prof. Håvard Holm, Dept. for Marine Technology<br>Research-fellow Trygve Kristiansen, Dept. for Marine Technology | |
| 1400-1500<br>IVT | **IVT infrastructure (site visit)** | Marine laboratories – Prof. Carl Martin Larsen (in meetingroom)<br>Civil engineering laboratories – Prof. Steinar Nordal (site visit)<br>Nils Smeland, student<br>Hilde Lysne, programme of study administration | |
| 1500-1700<br>IVT | **IVT/IØT students** | Nils Smeland, Environmental Engineering<br>Ane Christophersen, Marine technology<br>Per Gunnar Hagevik, Product Design Engineering<br>Petter Haugen, Industrial Economics and Techology Management<br>Caroline Skaarer, Industrial Economics and Techology Management | |
| 1700 Hangaren | **Review team dinner** | Review team, Kristin | |
| 1900 Britannia | **Review team meeting** | Review team, Kristin | |

| **Thursday 17 April 2008 – Group I - programmes of study at NT – management, staff, students and infrastructure. Basic Subjects** | | | |
|---|---|---|---|
| **Time and place** | **Purpose** | **Participants** | Comments |
| 0900 -1130<br>NT<br>Realfagbygget E1-118 all day<br>(entrance from Høgskoleringen, NT Faculty Administration) | **NT Programme management** | Prof. Anne Borg, Vice Dean<br>Prof. Berit Kjeldstad, Dept. head, Physics<br>Prof. David Nicholson, Dept. head, Chemistry<br>Prof. Tor Grande, Dept. head, Materials Technology<br>Prof. Sigurd Skogestad, Dept. head, Chemical Engineering<br>Prof. Bjørn Erik Christensen, Program chair, Nanotechnology<br>Prof. Jan Ketil Solberg, Program chair, Materials Technology<br>Prof. Øyvind Gregersen, Program chair, Chemical Engineering and Biotechnology<br>Prof. Ola Hunderi, Applied Physics and Mathematics<br>Section leader Jo Esten Hafsmo | |
| 1130-1200 | **Review team lunch** | Review team, staff and Vice Dean NT | |
| 1200-1400<br>NT | **Staff involved** in:<br>- *Chem. Biotech*<br>- *Materials* | Prof. Trygve Foosnæs<br>Prof. Svein Sunde<br>Prof. Lars Arnberg<br>Scientific assistant Rune Christian Kjøsnes<br>Prof. Edd Blekkan<br>Research fellow Susana Gonzalez<br>Prof. Per Olof Åstrand<br>Prof. Svein Valla | |
| 1400-1500<br>NT | **NT infrastructure (site visit)** | Organic Chemistry lab - basic subject (PhD-fellow Susana Gonzales)<br>Lab's for Hydrogen Technology, Hydro Electrolysis, Solar Cells (Prof. Svein Sunde) | |
| 1500-1700<br>NT | **Basic subjects – in particular mathematics** | Prof. Berit Kjeldstad, Dept head, Physics (physics)<br>Prof. Tor Grande, Dept. head, Materials Technology (chemistry)<br>Prof. Kjell Bratbergsengen, Dept. Head Computer and Information Science<br>Professor Lisa Lorentzen, Mathematical Sciences<br>Professor Kari Hag, Mathematical Sciences<br>Ass.Prof. Mette Langaas, Mathematical Sciences | |
| 1700 SiT Realfag | **Review team dinner** | Review team, Kristin | |
| 1900 Britannia | **Review team meeting** | Review team, Kristin | |

| **Thursday 17 April 2008 – Group II - programmes of study at IØT – management, staff, students and infrastructure. Basic Subjects** | | | |
|---|---|---|---|
| **Time and place** | **Purpose** | **Participants** | **Comments** |
| 0900 -1030<br>IØT, Sentralbygg I, 11th floor,<br>meeting room 1164 (library)<br>(enter via ”Gamle Kjemi” behind Hovedbygget) | **IØT Programme management** | Jan Morten Dyrstad, Dean<br>Olav Fagerlid, Vice Dean<br>Bjørn Nygreen, Programme Chair<br>Tim Torvatn, Deputy Dept. Head (studies)<br>Marit Rørvik, Programme of study secretary<br>Andreas Ulvær, student representative | |
| 1030-1230<br>IØT | **Staff involved** in:<br>- *industrial econ.tech.man*<br>- *non-tech (IØT)* | Professor Morten Levin<br>Ass.Prof Stein-Erik Fleten<br>Ass.Prof. Tim Torvatn (non-tech)<br>Doctoral student Bjørn Haugstad<br>Doctoral student Frank Henning | |
| 1230-1300 | **Review team lunch** | Review team, Vice Dean, Dept. Head? | |
| 1300-1500<br>IØT | **Innovation** - education, student activity, infrastructure<br>(presentations and discussion) | Sigmund Waagø (IØT) Entrepreneurship Centre and learning through practical experience<br>Erik Nikolai Stavseth (IØT) Entrepreneurship School<br>Karl Klingsheim (IØT/TTO) Courses in entrepreneurship<br>Bjørn Inge Haugan, Gløshaugen Innovation Centre<br>Andreas Palmstrøm, START NTNU | |
| 1500-1700<br>Realfagbygget | **Basic subjects – in particular mathematics** | See programme group I | |
| 1700 SiT Realfag | **Review team dinner** | See programme group I | |
| 1900 Britannia | **Review team meeting** | Review team | |

| **Friday 18 April 2008 – last day – internal work and oral report to NTNU** | | | |
|---|---|---|---|
| **Time and place** | **Purpose** | **Participants** | **Comments** |
| 0900-1330<br>Styrerommet<br>Hovedbygget<br>(2nd floor, East wing) | **Internal Work** | Review team | |
| 1330-1530<br>Styrerommet<br>Hovedbygget | **Oral Report** | Pro-Rector Julie Feilberg<br>Ingvald Strømmen, Dean IVT<br>Jan Morten Dyrstad, Dean SVT<br>Bjørn Hafskjold, Dean NT<br>Jostein Grepstad, Vice Dean Research IME<br><br><u>FUS (dean/vice deans of education):</u><br>Bjørn Torger Stokke, Dean, FUS Chair<br>Olav Fagerlid, SVT-IØT<br>Kristian Seip, IME<br>Svein Remseth, IVT<br>Anne Borg, NT<br>Ane Christophersen, student | |
| 1535 | **Departure to Airport by taxi** | | |

# D) The curriculum vitae of the review team

**Helen Dannetun** has a civ.ing. degree in applied physics and electrical engineering from Linköping University (LiU) in 1980. She received a PhD in applied physics in 1987 and became assistant professor in 1990, associate professor in 1996, and full professor in 2002. Her research has been focused on catalytic reactions on surfaces and especially hydrogen and hydrogen containing molecules on platinum and palladium. During her time at LiU she has had many different appointments and has served on numerous boards and committees. She was the head of the Department of Physics, Chemistry and Biology (2000-2003) and in 2004 became Dean of the Institute of Technology (the faculty of science and engineering) at Linköping University. She also has many appointments outside LiU and is presently the head of NORDTEK (a network for the institutes, and faculties, of technology in the Nordic countries).

**Sara Eriksson** is a student at the Royal Institute of Technology (KTH) in Stockholm, Sweden. She is studying biotechnology, MSc. in Engineering with specialization in environmental microbiology. Sara has been a student representative in the board of the School of Biotechnology at KTH, working for student rights, equality and educational development in different committees. She has also been working full time at the student union with educational affairs and during that year she was the student representative in the faculty board, the steering group and the president's advisory group at KTH.

**Knut Harg** has a siv.ing. degree in chemical engineering from NTH in 1974, and a Master of Science (Chem.Eng.) from the University of Wisconsin, Madison in 1976. He was employed by Norsk Hydro ASA for 32 years, holding various technology and management positions including Research Director (1995-2000) and president of two Hydro subsidiary businesses (2000-04; 2004-07). After a short period in StatoilHydro ASA, he is now a private consultant. He has been part of the evaluation committee for Chemistry and Biotechnology at NTNU, is a member of the Working Party on Education in the European Federation of Chemical Engineers, and is a programme evaluator for the Research Council of Norway.

**Helge Elbrønd Jensen** received his MSc in Mathematics from the University of Copenhagen in 1967. The same year, he became assistant professor, in 1972 associate professor and in 1988 full professor at the Department of Mathematics, Technical University of Denmark (DTU). His main research fields are functional analysis, discrete mathematics, signal analysis and coding theory. He has written several textbooks on mathematics and applications of mathematics, and received the IEEE Information Theory Best paper award 1991 and the Telecommunication Advancement Foundation (Japan) Prize 1998. Since 1992 he has taken on key management functions at DTU, first serving as Chairman of his Department (1992-1998). During the past ten years, he has served as the Director of Studies (1998-2001) and is currently the Dean of Education and member of the board of managers at DTU (2001- ).

**Terje Olav Moen** has a cand.scient. degree in physical chemistry from University in Oslo in 1981. He was then employed for 2 years at Norwegian Defence Research Institute (FFI) within alternative energy before he joined IBM in 1983. At IBM he worked in the area of telecommunications and had several internal courses on this subject and general IT and management. From 1989 he was employed in the Research Council of Norway with responsibility for energy research, basic natural science and technology research, and R&D strategy until 2007 when he joined Tekna as Director for Section for Science and Technology. In the Research Council he had various managerial positions and participated in the board from the employees. He also worked for a period in the IT department in the Norwegian Insurance

companies Storebrand and IF (1998-2000). During the years at the Research Council he participated in the evaluation of The Nordic Energy Research programme and is on several boards for R&D programmes.

**Elli Pyykkö** is taking an MSc Degree in Engineering at the Helsinki University of Technology (TKK), in the Information Networks degree programme (Faculty of Information and Natural Sciences). Since the start of her studies in 2002, she has been a student member of several administrative bodies at TKK both in the degree programme and department level. She has also been active in the student union of her university. Currently, she is finishing her master's thesis and working full-time in SimLab Enterprise Simulation Laboratory in TKK, where she has been employed as a researcher since May 2006.

**Jörg Steinbach** obtained his academic degrees Dipl.-Chem. (1980) and Dr. Ing. (summa cum laude) in Chemical Engineering (1985) from Technische Universität Berlin. From 1985 to 1996 he worked for Schering AG in Berlin. He held several different appointments, among others: Head of "Corporate Plant Safety". In 1994 he has been conferred the venia legendi for "Chemical Engineering". In 1996 he became full professor for "Plant and Safety Technology" at TU Berlin. After having served as Dean of Faculty for 4 years he was elected as 1st Vice-President of TU Berlin in 2002. He has held this position ever since. He is a chartered expert according to German § 29a BImSchG, a member of American Institute of Chemical Engineers, the CEO of AVI (Coordination Group of German Institutes of Technology for the Accreditation of Engineering Curricula), a member of the board of ASIIN, and since 2007 is the President of SEFI.

**Berit Svendsen** holds an MSc in Electronics from the Norwegian University of Science and Technology (NTNU) (1988), and a Master of Technology Management from NTNU and the Massachusetts Institute of Technology, USA (1995). She joined Telenor in 1988 as a Research Scientist. From 2000 to 2005 she was Executive Vice President and CTO of Telenor and also Working Chair of Telenor R&D. In January 2005 she took up the position as Vice President and Head of Telenor Nordic Fixed with overall responsibility for the fixed network business in Norway. From 2002 to 2007 Berit Svendsen was a member of the European Commission / IST Advisory Group. She joined Conax as CEO in May 2008.

**Peter Wieringa** obtained his MSc in Mechanical Engineering (1980) and his PhD (1985) from the Delft University of Technology (DUT). He was a fellow of the Royal Dutch Academy of Sciences (1987-91) and received the International Fogarty Fellowship in 1988 (NIH/USA). After research training at the University of Virginia, USA (1988-1990), he returned to Delft and became associate professor (1991) and full professor (2000). In his research, he has focused on the analysis of complex systems related to the human heart and microvascular system, and has in later years widened his scope to medical systems, control engineering and man-machine systems. He is an active member of international scientific communities in the latter fields (IEEA, IFAC). From 1996 onwards he participated in three Research Schools at DUT. He was chairman of the Department of Medical Technology and Mechanics (2000) and Director of Education and Vice Dean of the Faculty of Mechanical, Maritime and Materials Engineering (from 2005). Since 2005 he is involved in education governance and policy making at the TU Delft and has served on education review committees.