

Design Engineering

An Overview of Existing Programs¹

What follows are brief descriptions of the engineering design programs offered at the workshop participants' institutions of higher learning. This overview was drafted from the descriptions individuals submitted in response to the invitation to attend. Fuller versions will constitute an appendix in our workshop report: "Educating the Engineer of 2010 - the design turn in engineering"².

In reading through these brief descriptions, one can not fail to notice the innovative character of these relatively new programs - most did not exist more than a decade ago. Project based learning and design studios are a common ingredient; this means students take a more active role in learning. While the study of traditional engineering science subjects is there, its role is conceived differently than usual, providing the necessary conceptual and principled understanding of how things work when that understanding is needed in the semesters project or design task.

The context of engineering "problems" and of professional engineering design work is broadened: User interface is not just a question of ergonomics; understanding social context and the roles of all "stakeholders" is recognized as just as important as determining the arrangement of buttons on a controller. There is wide acceptance of the fact that designing today requires the efforts of a multidisciplinary team; it's not the province of an individual at a drawing board or laboratory bench. All stress the importance of collaboration with industry; in this, some have stronger ties than others.

Teaching staff differs from the usual in a traditional engineering department. Most program faculties are multi-disciplinary and must confront all the challenges of communicating and negotiating across domains. Some are fortunate to constitute a department in its own right. Most, however, are bound together by a commitment to this kind of innovative education and depend upon persons forming alliances across boundaries defined by disciplines and departments.

Faculty appear to be struggling with the right form of "research" with which they should be engaged. Some build their research atop student/industry project work. Administrative support is generally strong but rarely permanently assured.

Yet while these new and innovative programs show many common features, there are significant differences. They differ in their ideas about the meaning and scope of "design" - what it is, who is a player, what subjects the students will need to know in order to function effectively in practice. Some emphasize aesthetics more than others; some emphasize design methods. They differ too in the credits they require in engineering science subjects and to the extent to which they control the content of these courses; some require more traditional course work than others. Some take full responsibility for the their teaching, others leave this up to others who proceed independently.

1. Prepared for a workshop to be held at DTU, 19 and 20 October, 2006: *Design Engineering: Bringing back creative practice into engineering education*

2. The report of the workshop will build upon the experiences of others too, not included here, who have established new courses as well as programs in the same spirit as those described herein, e.g., at Harvey Mudd College, Stanford University, Olin College in the US, the Open University in the UK, etc.

The flexibility these programs exhibit with respect to their temporal organization, course requirements, and degrees granted also differs significantly. In the US, a four year undergraduate study, leading to a Bachelor's degree is the norm, though now many schools in the US are encouraging students to obtain a master's degree. These programs herein show more variety; not all grant a bachelor's degree after six semesters; most offer a master's degree program of two years duration following the three years prior study. Program language differs too; some teach wholly in English, others stay with their own native language. Differences of this sort may reflect differences in policies of different nation states, policies which, in effect, set entrance requirements. It may also have something to do with norms for accreditation. In the US, the criteria set by ABET - the recognized U.S. accreditor of college and university programs in applied science, computing, engineering, and technology - are pervasive and more or less universally respected. In Europe, the times are more dynamic; changing in response to the Bologne accords.

In our opening paragraph, we propose to publish a report "Educating the Engineer of 2010 - the design turn in engineering" as a follow-up to our workshop. This title is meant to play off the title of a recent report of the US National Academy of Sciences: "Educating the Engineer of 2020: Adapting Engineering Education to the New Century" - a report which recommends, among other things, that design should be an essential core in the education of engineers "...from the earliest stages of the curriculum". And schools should "...introduce interdisciplinary learning in the undergraduate environment, rather than having it as an exclusive feature of graduate programs". Noting that these are already core elements of the programs described herein, we expect that our two-day workshop will both lay out and analyze the challenges of renovating engineering education to better accord with professional engineering practice and provide a blueprint and working models of how it can be done ... now.

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Danish Technical University The Design and Innovation Program

Ulrik Jorgensen

Program structure

The Design and Innovation program at DTU consists of a bachelors curriculum of 3 years and a masters of 2 years in accordance with the tradition at DTU for typically giving 5 year masters programs. While the program until now has been conducted in Danish, the masters part will be given in English beginning in the fall semester of 2007. The chart shows the course requirements of the bachelors program, listed according to semester offered and the credit points associated with each course indicated by the horizontal length of each block.¹

The design & innovation bachelor curriculum matrix.

Semester	10 ECTS	15	20	25	30
1	User oriented design	Visual communication	Use and design of products	Mechanics and materials	
2	Product analysis and re-design		Technology analysis	Programming / Electronics	Linear and differential mathematical models
3	Design of mechatronics	Industrial design	Elective	Dynamics and oscillations	
4	Workspace design	Design of work processes	Elective	Electronics / Programming	Thermodynamic modeling
5	Product-service systems	Product life & environment	Elective	Light & materials	Signals & transformations
6	Bachelors project		Scenarios and concepts	Elective	Fields, fluid mechanics

Each semester, project courses (to the left in the chart) constitute the spine of the syllabus with a progression of challenges in various dimensions. The basic idea is to combine “learning by doing” in the projects with a structured learning sequence emphasizing elements of practice necessary to obtain specific competencies in key areas. Understanding and mastering design synthesis requires an apprenticeship within professional contexts. The student must witness the professional in action

1. Two conference papers describing the program, its purpose and conduct, are: Boelskifte, P., & Jorgensen, U., “Design & Innovation: Developing a Curriculum for Future Design Engineers at the Technical University of Denmark”, Engineering and Product Design Education Conference, Sept., 2005, Napier Univ., Edinburgh, UK, and Broberg, O., and Andreassen, M.M., “Learning Participatory Workspace Design in an Engineering Design Curriculum”, ICED 05, Melbourne, Aug. 2005.

to experience value based assessments and how this dialogue applies in working up one's own creations. The learning process is thus primarily based on interaction and experience in practice.

The courses in the middle of the chart cover the topics from technology studies and design practices, while the courses to the right provides the basic knowledge from natural and engineering sciences. The program has focussed on integration of subjects as a didactic cornerstone in the learning of the very abstract but fundamental science curriculum. The model is based on a problem oriented – but educator planned and controlled - learning process. A complex product is chosen as a reference (a bicycle, a refrigerator, a PLC device etc.) and analyzed focusing on selected basic phenomena. Scientific and technical principles suited to explain these phenomena are then introduced together with relevant mathematical models that can be utilized for a approximation of ideal relations between the phenomena.

What the chart *does not* show is the way the class hours of a course are spread over a week - and over the semester. The general structure at DTU - not solely that which governs the Design and Innovation Program - requires that the four hours of student contact, associated with each five point course, be held on a single half day of the week over the 13 weeks of the semester. There is an additional three week period tagged onto the end of each semester which is used in different ways by those courses requiring use of the additional time to meet the full point requirements of the course.

Different faculty do different things during the four hour, continuous block of time they meet with their students. Most split the period into two parts; one part - roughly half the time - is spent lecturing; the other part. in having the students work exercises. Some lecture the full four hours but include an occasional break. The project lab sessions can run all day if the points allow. Students can thus go off to do field work without worrying about getting back to DTU for another course meeting.

At the masters level, three specializations are offered within the framework of the Design & Innovation Program - Product Design, Systems Design, and Design & Innovation Management. They all share the common projects of the master's program but offer a different focus. As an example, the program structure of the specialization in Product Design is shown in the chart.

Product Design Specialization (example). Masters

Semester	10 ECTS	15	20	25	30
7	Holistic design	Design projects in companies	Design for interaction	Elective	Elective
8		Strategy, design and markets		Elective	Elective
9	Design methodologies	Innovation in networks	Products & consumption	Elective	Elective
10	Masters project (thesis min. 30 ect.)				

Program key characteristics

The Design and Innovation Program's key characteristics are:

- A heavy emphasis on project and design tasks; design courses run throughout the entire program over all semesters. Design, in its full complexity, is at the core of the program.
- Socio-technical analysis (building on findings from the Science and Technology Studies field) is similarly considered to be core both in perspective and content; it is integrated in with the teaching of design.
- The mathematics and science content, usually studied apart in a traditional engineering curriculum and taught independently via service courses to large numbers of students, has been oriented and adapted to fit the engineering objectives of the program and taught in specially designed courses. Other science and mathematics subject matter has been integrated in with the engineering science courses.
- The engineering science teaching is meant to be supportive of, and related to, the teaching within the project design courses.¹
- Responsibility for teaching the so-called 'generic skills' like communication and teamwork lies with all faculty and is integrated into the large projects in each semester and the smaller assignments included in most courses.

The students

The 60 students - the maximum the program is allowed to enroll - are all Danish speaking but different from the norm, i.e., from those who might choose to study a more traditional line in engineering. According to a survey of the first group of 60 students to enroll, conducted after they had completed the first semester, above 60% would *not* have selected to study at DTU had the new education not been available.

"Creativity" was high on the list of their interests; a number had been interested in studying architecture, or in attending a traditional design school, but saw it as too artistic; they wanted to build things, and know what made them work. Others had started university studies elsewhere - e.g., in business, in engineering - but had transferred over to join the Design and Innovation Program after one or two years.

Roughly 40% of the students are women, though this did not seem to be a factor in their choosing the program. Applicants had little contact with older students, already in the program, but this is understandable since the program is so young. Information about the program students *did* rely upon had come from a variety of sources: One had read a newspaper article; several had attended the April presentations of the different departments held at the Student Center; one attended "a day at DTU"; several had friends who were applying to the program while some had seen a brochure.

1. "...disciplines of basic engineering science are integrated into the more practice oriented disciplines, in combination with constructive and motivating project work." DTU, Dept. of Mechanical Engineering, Annual Report, 2002, p. 12.

Faculty see the students as different; they are “more demanding” - in a good sense -e.g., they ask more questions, they are not afraid to go out into the world on their own to interview people in connection with their design projects; they display an energy their other students - those taking their courses outside of the Design and Innovation program - lack. The students have formed a community, of sorts.

The faculty

The faculty come from a range of disciplines - manufacturing, materials science, mechanical engineering, anthropology, social study of technology, business, mathematics,.... Those responsible for the day-to-day conduct of the different courses - lecturing, student exercise sessions, project oversight, evaluation - hold different rank from full professor to two individuals without Ph.D. (Though all courses have a DTU professor at some level listed as ultimately responsible).

Not all faculty speak Danish; several courses are given in English – from the fall semester 2007 the Masters degree will be offered in English. Some courses employ student teaching assistants using undergraduates as well as graduate students.

Several faculty take on a broader responsibility, participating in more than one course, interfacing with industry, meeting more frequently together to ensure the program stays on track with respect to its goals. New faculty have joined the staff, but a core group from different disciplines remains in charge for the coordination of the program.

Reflection

The Design and Innovation Program at DTU is unique compared most engineering programs - in the students it attracts, in the central role that the social study of technology plays throughout the curriculum, in the emphasis upon the use of open-ended, design projects to actively engage the students, in the way the basic and engineering sciences are organized and taught, in the dedication and overall quality of the faculty, and in the extent of the involvement of students with the world of engineering practice - in real time.

Rensselaer Polytechnic Institute

Engineering Design - The Product Design and Innovation Program

Mark W. Steiner

Engineering design at Rensselaer is rooted in a mix of innovative curricular programs, academic laboratories, both required and special elective courses. Essential elements are the *Product Design and Innovation* program, (PDI) the *O.T. Swanson Multidisciplinary Design Laboratory*, the well established *Introduction to Engineering Design* core course, and the *Inventor's Studio* elective course offering. We focus on the PDI program¹ in this overview.

Product Design and Innovation Program

Rensselaer's Product Design and Innovation program, (PDI), illustrates how one can successfully integrate the humanities and social sciences (H&SS) into an engineering curriculum if one takes the latter seriously. A student who completes the eight semesters of this dual degree program, built around a studio design class each semester, integrated into a core-engineering curriculum, is awarded Bachelor degrees in both Mechanical Engineering and the Humanities and Social Sciences.

The program is administered through the Science and Technology Studies Department in the School of Humanities and Social Sciences. The studio design courses introduce students to a broad range of open-ended design experiences, where they learn how to combine cultural, aesthetic, and technical skills and knowledge with the insight and context of social concerns and issues.

Compared to typical engineering seniors, PDI students clearly distinguish themselves. They are comfortable and competent with multidisciplinary thinking and often at odds with the conventional mindset that tends to focus on disciplinary specialization. They represent the kinds of engineering graduates that organizations in industry, government and society are seeking - resourceful problem solvers and first rate technical professionals.

The chart on the next page shows the requirements of the PDI curriculum in Mechanical Engineering and STS². (There is a PDI curriculum in Management and STS as well).

1. <http://www.pdi.rpi.edu/>

2. http://www.pdi.rpi.edu/Documents/PDI_MechE_Curriculum_299_05-06.pdf

PDI Curriculum in Mechanical Engineering and STS

First Year

Fall		Credit hours	Spring		Credit hours
ARCH-2200	Design Studio I.....	4	ENGR-2020	Design Studio II ²	4
STSH-1110	Introduction to STS (First-Year Studies)	4	ENGR-1100	Introduction to Eng. Analysis	4
MATH-1010	Calculus I.....	4	MATH-1020	Calculus II	4
ENGR-1300	Chemical Principles for Engineers.....	4	STSH-2960	Design, Culture, and Society.....	4
ENGR-1200	Engineering Graphics and CAD ¹	1	ENGR-1300	Engineering Processes ¹	1

Second Year

Fall		Credit hours	Spring		Credit hours
IHSS-2500	Design Studio III ³	4	ENGR-2050	Introduction to Eng. Design with Prof. Dev. ⁴	4
ENGR-1600	Materials Science for Engineers	4	ENGR-2530	Strength of Materials	4
MATH-2400	Intro. to Differential Equations	4	ENGR-2090	Engineering Dynamics	4
PHYS-1100	Physics I for Engineers	4	PHYS-1200	Physics II for Engineers	4
CSCI-1190	Programming	1			

Third Year

Fall		Credit hours	Spring		Credit hours
STSH-4960	Design Studio V (Industrial Design) ²	4	ENGR-4960	Design Studio VI ²	4
ENGR-2350	Embedded Control	4	ENGR-4050	Modeling and Control	4
ENGR-2710	General Manufacturing Processes	3	STSS-4xxx	STS Advanced Option ⁵	4
ENGR-2600	Modeling and Analysis of Uncertainty ³	3	ENGR-2250	Thermos/Fluids Engineering I	4
STSS-4xxx	STS Advanced Option ⁵	4			

Fourth Year ⁹

		Credit hours			Credit hours
MANE-4940	Design Studio VIII	4	STSS-4980	STS Senior Project ⁸	4
MANE-4260	Design of Mechanical Systems ⁶	3	MANE-4020	Thermal and Fluids Engineering II.....	4
STSS-4800	Public Service Internship ⁷	4	MANE-4040	Mechanical Systems Lab.....	2
ENGR-4300	Electronic Instrumentation.....	4	MANE-4020	Thermal and Fluids Lab.....	2
MANE-4030	Elements of Mechanical Design	4			
ENGR-4010	Professional Develop. III	1			

¹ These courses may be taken in any order.

² PDI Studios II, V, VI, and VII satisfy the mechanical engineering requirement for the concentration elective.

³ For PDI students, Design Studio III can be substituted for one of the two STS concentration options.

⁴ IED is Design Studio IV.

⁵ Candidate courses include: STSS-4350; STSH-4230; STSS-4110; STSS-4250; STSS-4310; STSS-4560; and STSS-4650.

⁶ Design of Mechanical Systems is Design Studio VII.

⁷ This course satisfies the requirement for Professional Development II.

⁸ The STS Senior Project can be combined with the Capstone Design Studio to make an eight-credit capstone studio project.

⁹ See adviser for fall/spring order of fourth-year courses.

The heart and soul of the PDI program lies in its studio sequence, one studio for each of the eight semesters. Studios are taught by faculty from a variety of disciplinary backgrounds and levels of experience. The studio sequence includes the following:

Studio 1: Introduction of design as an open-ended process, critical thinking, interdisciplinary collaboration, observation and perception, communication and visualization.

Studio 2: Focuses on product development process with emphasis on problem definition, conceptual development and sketching; impact of design on society.

Studio 3: Course objectives are to understand the role of visualization and representation, and relationships between form and function.

Studio 4: An introduction to engineering design with emphasis on creativity, team work, and communication. Students are exposed to engineering design with a challenging design-analyze-build-test experience.

Studio 5: Focuses on social aspects of design with ethnographic techniques using example of design of educational technology.

Studio 6: Explores technical innovation and how design mediates the impact of new technologies on society and culture.

Studio 7: Engineering capstone design course that immerses students in a real world multidisciplinary design experience.

Studio 8: An engineering design elective: Inventor's Studio, independent study, engineering economics.

O.T. Swanson Multidisciplinary Design Laboratory¹

In their final year, students have access to Rensselaer's *O.T. Swanson Multidisciplinary Design Laboratory* (MDL), which serves as a capstone design studio, designed to prepare graduates to enter the professional workforce. The laboratory provides clinical experiences intended to build the student's confidence and teach them to integrate discipline-specific knowledge with practice on challenging, real-world design projects.

Over the past five years, since the MDL first opened, we have delivered results on 48 industry-sponsored projects to a wide range of companies including Albany International, Barclay Capital, General Electric, Harris Corporation, International Business Machines, General Motors, Pitney-Bowes, Lockheed-Martin, Northrop-Grumman, and United Technologies Corporation. In addition to defining a design task, sponsors provide a significant grant and join with faculty and staff in coaching and guiding students. In addition to industry-sponsored projects, individual entrepreneurs and public and private foundations have also sponsored projects; this serves to enhance and broaden the mix of project options for students.

1. <http://www.eng.rpi.edu:8080/mdl/>

Regardless of their source, the design projects are all open-ended and technically challenging . They engage students with a broad array of contemporary professional engineering concerns such as technology innovation and entrepreneurship, manufacturing productivity and quality, environmental conservation and alternative energy, and aids for people who are physically and/or mentally challenged. The multidisciplinary nature of projects is assured as students in the PDI Mechanical Engineering Curriculum have the opportunity to work with students majoring in materials, computer systems, electrical, biomedical, and industrial engineering. Past projects have included a wide variety of problem areas such as the following:

- Design and development of a new morphing wing structure to allow aircraft to respond to varying flight conditions and missions.
- Concept design, build and test of medical tools and instruments for minimally invasive harvesting of the saphenous vein used in coronary artery bypass surgery.
- Market research and feature development for a new car options package to appeal to young (so called Gen Y) buyers.
- Design and development of a steam test facility for evaluating new energy efficient steam turbine system design concepts.
- Concept development and evaluation of new energy efficient indoor air quality technologies.
- Design of systems that can be used to help seniors live safely and comfortably in their own home.
- Exploration of information technologies and system layout for a new investment trading facility.
- Design and prototype development of thin film sensors for corrosion prediction.
- Prototype development of smart adaptive control systems for factory automation utilizing CAD/CAM process knowledge.
- Design of a prosthetic device to help a young boy with Cornelia De Lange syndrome and no hands to eat independently for the first time.
- Concept development and engineering test of a wind turbine powered catamaran.

Design offerings at RPI also include an **Introduction to Engineering Design** course - a sophomore/junior multidisciplinary course intended to introduce students to the engineering design process. This too is a project based course taught in a studio environment. Learning how to communicate in the context of the design process and learning how to work in a team environment are integral elements to this course.

The **Inventor's Studio** gives students the opportunity to invent and patent. This unique course is designed to provide a challenging capstone design experience for engineering students from different disciplines and backgrounds. For some, the experience has led to entrepreneurial activity. In the recent history of the course, five patents have been issued. (Several are pending).

Ostfold University College, Halden, NORWAY

The Industrial Design Program

Petter Øyan

The Industrial Design Program at Ostfold, located in Halden, in the southern part of Norway, was started 2001 as a copy of the first three years of the five year design education at the Norway University of Science and Technology (NTNU - *Norges teknisk-naturvitenskapelige universitet*) in Trondheim. An agreement with NTNU was established allowing students who had successfully completed the three year (six semester) BA in Industrial Design at Østfold university college to be admitted to the fourth year of NTNU's 5 year, Masters (Sivilingenior) program in Industrial Design.



Originally, over the first two years of the Industrial Design Program, the faculty of engineering at Ostfold were only responsible for teaching the traditional engineering courses. Students did a design course in association with an external, but local, partner who was sited about 30 kilometers from the campus at Sarpsborg. Students reported that they felt like “designers” when they were off campus and “engineering students” when they were back at the college. The external design instructors were not responsible for, nor did they participate in the day-to-day organization and planning of the students’ studies.

In 2002 the department recruited a design professor to ensure internal competence and control of the development of the industrial design program. Petter Oyan began work in this position starting in August, 2003 and, from that point on, the faculty of engineering developed and organized the design program as an integral part of the engineering department. All educational activities of the program were located on campus and an instructor was hired to teach the first year design course and model making. In addition, a number of “guests” with experience in design teaching were brought in to teach on campus.

The staff has since been reorganized and now includes five members of the faculty of engineering and a number of guest lecturers. They are responsible for all of the design courses and most all of the traditional engineering science courses. In addition, mathematics and physics, as general courses, are considered the responsibility of the department.¹

1. The engineering department is a separate part of the university and has its own teaching staff for the so called “general courses”.

Focus

Early on, most students express an interest in going on to obtain a master's degree; a fewer number seek to gain employment immediately upon passing their BA exam. But we find that even those who go directly to work in industry often choose to enroll in a master's course of study after one or two years on the job.

This means that we must allow for two student options - employment and further study. Students who have gone immediately to work after their BA exam have obtained jobs in product development departments or design jobs in design consultancies. The master's programs chosen by graduates cover a wide range and include design programs at NTNU-Trondheim, AHO -Oslo, Umea, Politecnico Milano, Glasgow, Aalborg, Goteborg as well as engineering programs at NTNU and UMB-As, and business development studies at UMB.

Curriculum - structure and method.

The chart on the the last page shows the curriculum. The design courses, which constitute the core of the program, extend over two semesters of each of the three years. These courses are taught as problem-based, project work. The intention is that students "learn by doing" immersed in a multi-faceted, multi-disciplinary context. With the increased flexibility of the teaching staff, the method is also used as a supplement in the traditional, lecture-base science and technology courses required of our students. Most all of the problems they address in these sessions are coordinated with the tasks the students address in their core design project work. To provide students with a more complex, interdisciplinary learning situation, program faculty have re-organized the curriculum so that the course "Design Process" (IRD 22006), offered in thesecond year, is open to students from other faculties; mainly business and language students participate as part of their business development course.

The construction of the courses for collaboration between the business and language and the engineering-design students might look complicated, but it works quite well. Both The "Design Process" course and "Project Management" (IRD 37006) courses are obligatory for the 3rd year business and language students; "Project Management" is an optional course for the 3rd year *design* students. This course is a prerequisite for students from Industrial Design, as well as the other faculties, choosing to join the research-based projects.

Interdisciplinary design and product development is again the focus of those students electing to participate in an international competition, the "Shell Eco Marathon", where student teams design, build and race a fuel-efficient car at an event in southern France. Ostfold students first participated in 2005. This kind of project provides the students from Industrial Design with the opportunity to work with and learn from other students at Ostfold university college in business, language, entrepreneurship, information technology and film studies. Engineering students at UMB also join the team. In addition, the students work directly with a wide range of firms on tasks such as 3D milling of forms to arranging promotion events and even producing a TV documentary to show to political sponsors.

The students receive academic credit for this project work; for the 3rd year students, this is their Thesis Work and also the basis for Project Management - a total of 25 ECTS. The 2nd year engineering design students are assigned exercises in "Statics and Mechanics of Materials" and "Man-

ufacturing Technology and Production Management” and/or a 5 ECTS optional project within “Design Case extended”. The team for 2005 included 6 Industrial Design students, 5 Entrepreneurship students, 2 French and International Marketing students and, as a support team, 5 Industrial Design students from the second year. The team for 2006 included, 2 Industrial Design students plus 3 Entrepreneurship students on the same team and, as support teams, 4 Industrial Design students from the second year, 5 Information Technology students and 3 Innovation students.

Collaboration with industry and research centers.

Ostfold university college has a long tradition of cooperating with industry; businesses come back year after year to propose “real world” projects for our students to engage. This greatly enhances the effectiveness of the instructor’s class room teaching while, at the same time, exposing students to competent and experienced, engineering design practitioners. To assure this result, industry participants join project steering committees and follow the students’ progress from beginning to end in cooperation with the instructor who is responsible for the course.

The program also has strong connections with the Institute for Energy Technology - IFE, an international research institute for energy and nuclear technology, also located in Halden. One division of the IFE, the Halden Virtual Reality Centre (HVRC) which focuses on Man-Machine interaction, proposes several student research projects each year. This affords the students the opportunity to base their project design work on contemporary and professional research and introduces them to research environments.

We are now also working with the Norwegian School of Veterinary Sciences and the Norwegian Defence Research Establishment, FFI, on research based projects. This year, 5 Industrial Design students, as a team, worked with IFE and FFI on a coordinated, research-based design and development of a handheld control device and a wearable computer system. Collaboration with the Halden Virtual Reality Centre has gone further: In september of this year (2006), the Industrial Design Program announced that students would be able to pursue graduate study and research, leading to a Ph.D. in interaction design, in cooperation with IFE.

These initial collaborations with established research centers on student projects provides - in what might be called a “bottoms up” approach - a basis for developing research programs in the design department. To support this development, we have also started research on how to improve teaching through realistic, multi-disciplinary projects, based on experience from the projects mentioned above. These projects all use the thesis work as a basis for projects and include project management as a method. For the design students, the project work also includes addressing user friendliness and creative and aesthetics aspects through design methodology. This last point has attracted great interest from research center partners.

Future developments

The future development of the Industrial Design program will be revised during 2006-07 in a process in which the teaching staff, past and present students, and external partners will be included. One point we have already begun to strengthen is the aesthetics dimension which we fear might be forgotten in engineering design courses because we experience how strongly our industrial and research center partners value this knowlege.

HMB Industrial Design 2006 - 2009		Design courses are coloured, interdisciplinary courses are blue.				Status pr. 16. Sep. 2006
1. year 2006-07	2. semester	3. semester	4. semester	5. semester	6. semester	
Engineering Mathematics 1 IRF10004 10 ECTS	Statics and Mechanics of Materials IRF20005 10 ECTS <i>Assignments relates to project work</i>	Manufacturing Technology and Production Management IRF21006 10 ECTS <i>Assignments relates to project work</i>	Logistics, Quality and EcoDesign IRD30006 15 ECTS	Thesis Work IRD37506 15 ECTS <i>Industry or research project based Group project</i>		
Design-techniques and Communication IRD11506 10 of 20 ECTS <i>Project based</i>	Design-techniques and Communication, coordinated project 5 of 20 ECTS	Engineering Mathematics 2 IRF20004 15 ECTS	Interaction Design IRD30506 10 ECTS <i>Industry or research project based</i>	Optional Courses 10 ECTS		
Basic Computer Programs and basic CAD IRF13706 5 ECTS	3D-modelling, Visualization and Animation IRD12005 10 ECTS <i>Partly project based</i>	DesignIntro and DesignCase IRD21606 15 ECTS <i>Industry or research project based</i>	Machine Elements IRME30004 10 ECTS			
Physics with Mechanics IRF11306 15 ECTS	DesignProcess IRD22006 10 ECTS <i>Coordinated with projects from DesignIntro, DesignCase or equivalent projects</i>					
Optional courses:	During summer holidays: Summer-design-school Göteborg, Sweden IRD22503 10 ECTS	IRD21606 DesignCase extended 5 ECTS Coordination of tasks from design- and science courses. Participation in HMB internal project collaboration with other faculties, HMB governed R&D projects, HMB business-associated projects Design practicum in industry - for exchange students IRD31504 15 ECTS	IRD37506 Thesis Work - extended 5 ECTS. Design essay on free design related theme Coordination of tasks from design- and science courses. Participation in HMB internal project collaboration with other faculties, HMB advanced R&D projects, HMB business-associated projects Work. 10 ECTS <i>Coordinated with Thesis Work or equivalent projects</i>			
Project weeks:	1: Thematic design assignments, excursions 2: Thematic design assignments, excursions 50% student planned	1: Thematic design assignments, excursions	2: Thematic design assignments, excursions 50% student planned	1: Workshop for organizing and coordinating project work 2: Project week reserved for thesis work		

Aalborg University

Architecture & Design, The Industrial Design Program

Marianne Stokholm

Aalborg University's Ba/Msc programs in Architecture & Design with specializations in Industrial Design (focused on here), Digital Design and Urban Design were established in 1997¹ under the auspices of the Faculty of Engineering, Science and Medicine. In this, faculty were motivated by a reported demand for employees that were able to serve as a link between the traditional architect/designer and the engineer, a desire to attract more students into engineering, and a wish to challenge and inspire the traditional education programs in engineering at Aalborg to continued development. International developments in the design profession pointed to an expansion of the designer's role especially in the industrialized countries so founding faculty aimed to strengthen the focus on the design process broadly conceived, not focusing only on Product Design in a traditional sense. The *Architecture & Design*, curriculum and the specialization in *Industrial Design* would consequently have a profile that differs from the other design educations in Denmark²

In 1997 50 students began the first year's *basic program*, which was a joint program for all students studying under the Faculty of Science and Engineering. In 2006, 110 students entered the bachelor's program in Architecture & Design and 28 students began the MSc program in Industrial Design.

Originally, members of the Departments of Development and Planning (architects and urban planners), of Building Technology and of Mechanical Engineering (engineers) with assistance from external consultants (engineers, architects and designers) established the foundation of the *educational program* in Architecture & Design and staffed the program. Today's actual Department of Architecture & Design was established later (in 2001).

As with all education at Aalborg, the curriculum is based on *Problem-based Learning* in which the majority of the courses, *project unit courses*, are applied and evaluated through project work carried out in groups. Other, more traditional, courses are required and there the student's efforts are evaluated using individual exams. Close co-operation with the business sector in the students' project work is the norm. Aalborg University's Network Centre ensures continuous contact between students and businesses through the publication of *Project Catalogues*.

1. See brochures, some in English, at http://www.aod.aau.dk/AOD_Forside_6_juni_2005/brochurer.htm

2. Being that the traditional educational programs within architecture and design are all affiliated with the Ministry of Culture, the establishment of this program was the first of its kind at a Danish university affiliated with the Ministry of Science, Technology and Innovation.

The paradigm for teaching was set at an early stage, as *Integrated Design* where a variety of professional areas would be integrated, e.g. through a cross-disciplinary team of teachers focusing on the linkage between designers and engineers. The distribution of courses and student activities reflects mixed input from the fields of engineering, architecture and design, supported by other scientific disciplines represented at the university. In the project courses, each group is guided by a two - a main and assistant supervisor, one with a background as a designer and the other being an engineer.

The teacher-corp for the architecture & design part of the curriculum has mainly been assembled from outside of Aalborg University; the majority of the members of this group are architects, urban planners and industrial designers, many of whom have practice experience. The engineering section has been manned with teachers from Aalborg University. Teaching within Industrial Design specialization is currently handled by approximately 10 engineering faculty from The Department of Mechanical Construction and the Department of Production, and by a similar number of industrial designers from The Department of Architecture & Design, including 1 professor, 4 associate professors, 2 assistant professors and 2 Ph.D. students.

The Educational Program Overview

The program has three phases. Entering students are occupied in the first two semesters of the first year with a *basic program* which includes an introduction to Problem-based Learning (PBL), project work, cultural studies, etc. The BA program, which covers semesters 3 - 6 over the subsequent 2 years is, in principle, an interdisciplinary program across the fields of Industrial Design, Digital Design, and Architecture and Urban Design with project work being carried out within all three areas. In the final year - 5th and 6th semesters - the students specialize and choose a project topic within one of these areas such as Industrial Design. The masters program, of two years duration comprises the specializations shown below.

Arkitektur	Urban Design	Industrial Design	Digital Design	Semester 7 - 10
Miniprojekt	Specialiseringsrettet bachelorprojekt			6
Miniprojekt	Program og koncept			5
Bebyggelsesdesign og digital kommunikation			Miniprojekt	4
Produkdesign		Bygningsdesign		3
Modellernes virkelighed (fra koncept til virkelighed)				2
Miniprojekt	Virkelighedens modeller (designkoncepter)			1

The BA Program

The bachelor program can be described as an education in *Basic Design* and *product design* (Industrial Design). The students receive an inclusive introduction to the field that is related to the creation of new products, buildings and urban plans; to the relationship between model and reality;

to phases, methods and methodologies that are related to analyses; problem statements and syntheses; to the historical background and various tools and applications of relevance to the work and communication useful in project work, not the least in information technology. An important aspect of the project work is the process evaluation in which students reflect on the design process, their group work, and their own learning. This reflection is supported and supervised by staff of *The Pedagogical Development Centre* at Aalborg; they play an especially important role in the first year of the program.

The program is intended to provide a common basic education in architecture and design. In Denmark and elsewhere, Industrial Design is a specialization commonly located either at Arts & Crafts institutions or at universities with engineering programs and is similarly influenced and constrained by either one of these two monocultures. Industrial design program faculty at Aalborg have been very conscious of the strengths and weaknesses of both of these perspectives on design and the potential they offer for innovation and breaking with tradition. Staff continually experiment with co-operation and integration across the design disciplines represented within Architecture & Design and within the various engineering disciplines. The multicultural environment and daily dealings with colleagues from different educational backgrounds ensure that attitudes and means of professional communication and co-operation are constantly challenged.

One consequence of this interdisciplinary mixing is that the students specializing in the area of Industrial Design work in a very context-oriented way, integrating user needs with knowledge of production methods, technical issues, material behavior, etc. The relationship between the general, the basic and the professionally related topics is dynamic and challenges teachers, researchers and students alike in their perception of subjects and disciplines. Such challenges create a fruitful uncertainty ensuring innovative thought and action.

The MA Program

Students from Aalborg University may choose a master's programme within the specialization that concluded the project work of their bachelor program. Industrial Design is taught only in English, and it was devised as a specialization within a more general program in product design. Thus, students are presumed to have fundamental knowledge and experience within project work relating to product design/product development, either in terms of engineering or design. Students from several countries are now following the master programme for one semester, or they have applied for the whole 2 year master programme. These "external students" are assessed according to their specific backgrounds. The last group begins the master's programme with a course in PBL, and subsequently attend the same program as internal students.

The Master Program specialization in Industrial Design provides, what can be considered, an education in *Advanced and Strategic Design*. The students acquire theoretical and methodological tools enabling them to handle integrated design at an advanced level *from Product design to Strategic design*, individually as well as a participant, facilitator and leader of cross-disciplinary groups.

The curriculum is structured around semester themes - System design, Advanced Integrated design, Strategic design - tracking a progression in the complexity of the design process over semesters 7 -9. The students do a masters thesis their final semester. Each semester embodies a specific approach to design as process, supported by courses in design theory and methodology of

relevance to the given context. Additionally, there are courses within specific subjects. The choice of specific project topics- e.g., products, service, business - is subject to this structure as it is perceived by faculty as a means for learning. The goal is the development of competencies for managing the complex integrated design process.

The semester plan is shown here.

7th Semester Total ECTS credits, 30

Main Project: Systemic Design 16 credits

Project courses: - Design Theory and Methodology I: Value analysis, concept development, System Design 2

- System Technique: humane, social-technical and technical dimensions 1
- Culture analysis and qualitative methods 1
- LCA (Life cycle analysis) 1
- Presentation technique 1
- FEM (Finite Element Method) 1

Mini Project: Problem based learning in a context 5 credits

Project courses: - Project Organized Problembased Learning 1
- Industrial Design experiments 1

8th Semester Total ECTS credits, 30

Main Project: Advanced Integrated Design 16 credits

Project courses: - Design Methodology II 2
- Technical Product Development 2
- Active Virtual Models in Product Development 2
- Modern Production Methods and Systems 1

Mini Project: Concept Development 5 credits

Project courses: - Concept Development and Presentation 1
- Design Practice and Competition 1

9th Semester Total ECTS credits, 30

Main Project: Strategic Design 18 credits

Project courses: - Design Theory 1
- Design Methodology III 2
- Organization and Management 2
- Production Innovation Technology 1
- Knowledge Production and Reflection 1

Mini Project: Creativity and Innovation Management in an Interdisciplinary and International Context 3

Project courses: - Creativity and Innovation 1
- Development in an Interdisciplinary and International Context 1

10th Semester Total ECTS credits, 30

Main Project: Master Thesis 30 credits

An important aspect of any project work is the process report in which the students account for the theories and methods that they have chosen to apply, how they have been implemented, in which way(s) they have supported the project work and which general experiences the students have obtained in the process. This “*reflection on action*” furthers “*reflection in actions*” and is considered indicative of the professional level of the design process and of the students’ level of competence.



Leap, a Graduate project from 2004: A hospital bed for children in the three months - three years age group. New functions and techniques have been developed by involving various users of the bed in the user-oriented design process.

Traditionally, education in industrial design has been structured around the product that is being designed using a pedagogy based on an exemplary principle where design process is taught primarily through examples and demonstrations. Such an approach tends to focus only on the particular material result of a design process - the artifact alone - and fails to give process the attention it is due.

Faculty chose NOT to use this model, because they hold that it is *mastering the design process* that characterizes the designer’s profession. Of course, the types of assignments that the students can work over the course of a two year program are limited; upon completion of their studies and in their ensuing professional careers they will certainly work with other types. But a basic training in managing the design process *in general* will provide them with vocational ballast that is applicable in many different assignment types, including those that are currently unfamiliar, and which they can continue to build upon for the remainder of their professional career.

Student employment

90% of the masters specializing in Industrial Design have found employment within a year of completing their education. (*A&D kandidatundersøgelsen, 2005*). The majority are employed at manufacturing companies and design consultancies, large and small alike, but also within the service industry and at public institutions. Some have established their own consultancies. They work as engineers, designers and project managers. The fact that the master education is in English specially qualifies the students to work in companies with a strong international profile or in R&D-departments in countries far from Scandinavia. The employers and business partners often emphasize that the very specific holistic blend of engineering skills and knowledge, and the scientific approach combined with the ability to handle aesthetic and creative matters in project groups are highly appreciated. Often, the ability to combine the methods and tools from different professions in a transparent and systematic way puts the candidates in positions as project managers in innovative projects.

The education entitles the masters to admission in *The Danish Society of Engineers (IDA)* and *The Union of Danish Designers. (DD)*.

Reflections

An important factor in the successful realization of this education in Industrial Design has been establishing a common perception of *Integrated Design* across the various educational backgrounds and professional understandings of the contributors.

The team of teachers at the MA programme is composed of engineers from a variety of departments and designers with practical and theoretical experience respectively. There has been a steady influx of new employees who have brought with them very different perceptions of educational culture, and different understandings and expectations, professionally as well as personally.

A simple visualization of Integrated Design presented by a consultant (who is now a professor with special assignments in Integrated Design) during the preparatory work in 1996 has, through the interplay between development and application, become a theoretical, practical and visual tool – *a model of Integrated Design* – that still serves as a platform and a tool in the development of the education.

The establishment and maintenance of this common platform and the co-operation at the education has given rise to heated debates. From being offensive and sometimes even aggressive they have gradually become more dynamic, constructively challenging and even innovative. Thus, we can conclude that we must continuously take our own medicine (Integration) in order to maintain the situation.

The process may be compared to mixing oil and water. It must be activated all the time in order to exist.

Further information:

Stokholm, M. (2006). *Design Compass – a simple tool for managing the complexity of design*. Proceedings D2B-1st International Design Management Symposium, Shanghai, p.103-111, Salford, Greater Manchester, UK: The Adelphi Research Institute Creative Arts & Sciences, The University of Salford, 2006.

Stokholm, M. (2005). *Design Compass – improving interdisciplinary communication on design*. Design Matters no. 10, p.54-57, Danish Design Centre, Copenhagen.

Delft University of Technology

Industrial Design Engineering, Bachelors Program

Norbert Roozenburg

In September 2003 the Delft Faculty of Industrial Design Engineering converted its five-year curriculum into a three-year bachelor program followed by a two-year master program. Initially three new master curriculums were introduced: *Integrated Product Design*, *Design for Interaction* and *Strategic Product Design*. Now the school is developing a new bachelor curriculum, which is to be introduced in September 2007.

Notwithstanding the positive quality assessment by an international committee under the auspices of the Association of Universities in the Netherlands, the school decided to aim for a radical revision of its bachelor curriculum in order to overcome some persistent weaknesses of the current and past programs, in particular, the lack of utilization of engineering sciences and behavioral science in design projects, the excessive length of time the student needed to complete the program, and low success rate as measured by the number who completed relative to the number who began the program.

A complete revision of the current bachelor program was also required because the three Dutch Universities of Technology have agreed to adopt a major-minor structure for all their bachelor programmes.

Profile of the IDE bachelor:

The development of the new curriculum started with a review of the competence profile of the industrial design engineering graduate. From interviews with practitioners, it was concluded that, above all, the bachelor program should be seen as a stepping-stone to a master program, and that the new program should stay as general and multidisciplinary as the current program. So with regard to the teaching objectives only shifts of emphasis were pursued. The most important objectives are: equal attention in projects to all phases of new product development; greater emphasis on the scientific justification of design decisions; more attention to the international context of product development; and greater flexibility in the study paths made available to students.

Educational concept

A persistent problem of the Delft Industrial Design Program (IDE) has been the gap between theory and practice. IDE students take courses in engineering sciences, human sciences, mathematics, statistics and the like; however in tackling practical design projects, they fail to apply this knowledge to the extent that their design would benefit. They tend to rely upon their intuition and experience. In our view, this derives from the compartmentalized disciplinary structure of the current IDE curriculum. Mechanics, mathematics, material science, as well as ergonomics and consumer behavior, etc., are taught in isolation and often with an emphasis on abstract theory without much reference to concrete practical problems. As a consequence many IDE students are not motivated to study these topics, and tend to postpone the courses concerned. Moreover, students who *have*

passed these courses, with or without delay, are often unable to apply their new theoretical knowledge when working on concrete design problems.

To address this problem in the new curriculum more attention will be paid to the development of the student's competencies. Knowledge, skills and attitudes will not be conveyed in mono-disciplinary courses in isolation from practice. Instead, beside project-based design courses, the new curriculum shall comprise large thematic multi-disciplinary courses in which new knowledge and skills are acquired in the context of authentic problems typical of engineering practice.

The program

The Delft academic year runs for 40 weeks, divided in four quarters of 10 weeks duration. The study load is 42 hours per week. In the first two years two 7.5 erts courses per quarter have been scheduled. The courses are much larger, in the sense that they cover more ground, than in the old curriculum, and consequently the number of courses is much smaller. By this we hope to improve the success rate and the average study duration, as student will no longer need to divide attention among many different parallel courses. Within the courses, students will see a mix of lectures, discussion groups, exercises, projects, etc. In the third year students follow a one-semester minor program of their own choice and two optional courses. A 10-week bachelor-final project concludes the program.

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Year 1	PD1 - Introduction IDE	Products in Action	PD2 - Conceptual Design	Mechanical Engineering Design
	Man and Product	Product Experience	The context of Product Development	Research for Design
Year 2	Product and Movement	PD3 – Strategic Design	Electronic Products	PD4 –Embodiment and Detail Design
	Strategic Product-Innovation	Industrial Manufacturing	Technical Product Optimization	Modelling and Simulation
Year 3	Minor		Optional Course 1	Bachelor Final Project
			Optional Course 2	

Figure 1 New bachelor curriculum of Faculty of Industrial Design Engineering, Delft University of Technology

Program Design Projects

A series of design projects (PD1 to PD4) forms the core of the new curriculum. The primary objective of these projects is integration of knowledge and skills. The complexity of successive projects increases from one project to the next, whereas the intensity of staff support decreases.

The very first course of the bachelor program is PD1, an introduction to the different aspects and activities of product development. We expect that this practical beginning will strengthen the stu-

dent's motivation for more theoretical courses, as they will better understand the need and use of different kinds of knowledge and skill.

The course PD2 focuses on the phase of conceptual design, both from the point of view of users and technical functionality.

In the course PD3 students do not receive a design brief, but are challenged to generate a new business idea for a particular company. So PD3 starts in the strategic “fuzzy front end” of product development. But the students must demonstrate the feasibility and quality of their ideas by working them out into concept designs PD4 starts with conceptual design and runs into the phases of embodiment and detailed design. In this course students must completely work out their design concept and prove its viability by different forms of modelling -e.g., a virtual or material prototype.

The series of design projects is concluded by the bachelor-final project in which student, working for the most part as individuals, must demonstrate their competence.

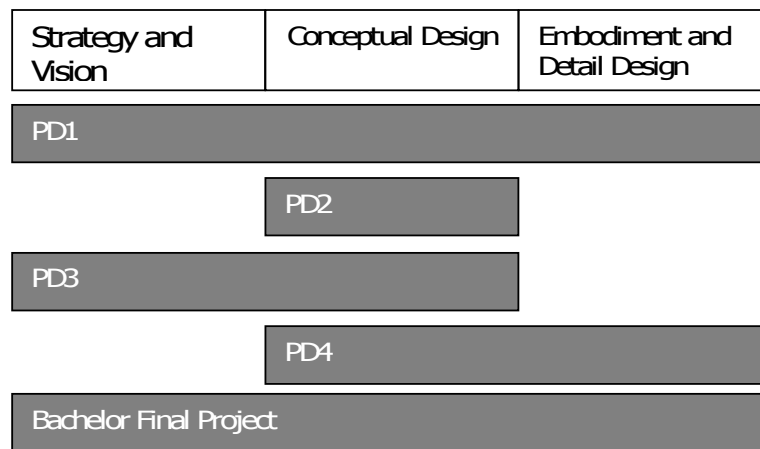


Figure 2 Phases covered by the design projects

Thematic courses (see figure 1) provide the knowledge and skills to be integrated in the design projects. Also the thematic courses are directed towards the development of the student's competencies. This means that subject matter, study tasks and assignments are always related to realistic problems that designing engineers might encounter in practice. Contrary to the design courses, which are project-based, the thematic courses make use of a spectrum of active educational forms. Contrary to more traditional ways of teaching, all thematic courses are multidisciplinary. For example technological courses like “Products in Action”, “Mechanical Engineering Design” and “Product and Movement” in a coherent way combine issues from technical components, material science, manufacturing, mechanics and mathematics. The same applies to the other thematic courses.

Eindhoven University of Technology, The Netherlands

Industrial Design Program- The design of intelligent products, services and systems

Kees Dorst

The Department of Industrial Design at *Technische Universiteit Eindhoven, TU/e*, started the Bachelor's program in September 2001. Rather than the traditional, broad field of Industrial Design, this Department has opted for the field of 'Intelligent products, systems and services' to capitalize on modern developments in sensor technology coupled with continuing advances in information systems technologies. Departing from a world in which products, systems and environments have been basically passive 'things', into an era where products, systems and environments will *actively engage* with the user, the bachelors and masters programs in industrial design aim to prepare students to design and produce *intelligent* products, environments, systems and services - systems and environments that span the divide between the physical and the digital worlds.

Students, in this new design discipline, should be able to integrate several of the traditional design fields: their knowledge base should span elements of Industrial Design, Interaction Design, Software Design, Systems Engineering and Mechanical Engineering. Technology Management is an important element too, because the successful development of intelligent products, environments, systems and services will often require the collaboration of companies and research institutes unaccustomed to working together, i.e., many of these products and environments require the use of a physical network and digital infrastructure. Recognizing the difficulty of establishing efficient and effective collaborations of this sort, the development of intelligent products and environments requires the development of new business concepts. It will also require a clear understanding of the needs of the prospective users, and on a subtle and intelligent design of the interaction. User needs research and user testing are key skills developed in the program.

The department has opted for an original, *competency-based* educational model in which students work on their competencies as Industrial Designers in a company-equivalent setting: by carrying out realistic projects and individual assignments *rather than following lectures and taking exams*. This principle is used throughout the study, right from the first day of the Bachelor's program.

In the Bachelor, the students learning takes place against the background of 4 application domains: *Home, Health, Work* and *Entertainment*. These Domains not only represent different design content, but also different approaches to design (e.g. the Domain Home concentrates on social and cultural issues, the Domain Work is more functionally oriented, Entertainment is more geared towards experience design). In the Master course, students currently can choose between two kinds of intelligent products, systems and services in the two master tracks *Empowering People* (mostly product-oriented) and *Intelligent Spaces*.

Masters are required to be independent practitioners within the Industrial Design profession, and thus able to understand the complicated challenges of designing intelligent products, systems and services, and to initiate and execute the research and design activities that will lead to the creation of a successful solution. They are also required to gain more specialized in-depth knowledge,

insights and skills within a specific area. In the Masters programme, the student can specialise in terms of the career perspective. We expect about 80% of the students to become a designer who will enter the labour market after graduation. 15% of the students will specialise as design researcher and prepare for a PhD after their Masters.

The educational program

The TU/e Industrial Design Program is based on *six core competency areas* and *four meta-competency areas* which are fundamental to the professional development of the designer of intelligent systems. (see Table 1 – the core competency areas are numbered 1-6, the meta-competencies are labeled A-D)

Table 1: ID Competency Framework

Core competency area	Meta competency area
<p>1. Ideas and Concepts Design concept generation and communication</p> <p>2. Integrating Technology Engineering principles of operation of sensors, control, materials, manufacturing, technology integrations and systems level integration</p> <p>3. User Focus and Perspective User-centered and interaction design</p> <p>4. Social and Cultural Awareness Design history, socio-cultural trends, sustainability</p> <p>5. Market Orientation Marketing and business aspects like identity, strategies, management</p> <p>6. Form and Senses Visual language, auditory design, haptics, symbolism & semantics</p>	<p>A. Multidisciplinary Teamwork, Communication</p> <p>B. Design and Research Processes</p> <p>C. Self-directed and Continuous Learning</p> <p>D. Analysing Complexity</p>

In this competency-centred program, learning and working come together. Throughout each semester, the student, considered “a junior employee”, engages learning activities in the form of team projects, individual projects (taking up about 60% of a student’s time) and assignments. An assignment is a 40-hour special subject in which the student is challenged to gather knowledge and/or skills under the guidance of an expert (e.g.: ‘mathematical modelling’, ‘programming in C++’, ‘semiotics’, ‘user testing’, etc). Although the students is free in principle to choose any assignment they feel will best fit their competency development, they will be guided towards specific competency areas by their competency coaches. Often students are advised to take a specific assignment to stimulate their progress, and in exceptional cases the completion of a specific assignment can be one of the conditions imposed on the student in an assessment. Thus the progress of the individual student is monitored and assured.

Upon completion of these activities, evidence of learning is displayed via models, prototypes(?), reports, and presentations - 'deliverables'. The learning activity is not an end in itself. While doing

a successful project or assignment is, of course, quite rewarding and motivating, the student is meant to see these tasks as means to develop the desired competencies by acquiring and using new knowledge, skills and attitudes. Each student has to reflect on his or her activities and writes a 'self evaluation' every semester. Furthermore, the student receives written feedback from experts on the deliverables and competency development in the learning activity. All descriptions, evidence, reflections and feedback are bundled into a development portfolio. The overall competency development of a student is assessed every half year, based on the student's self evaluation and the development portfolio.

In this curriculum, the difference between Bachelor and Masters is based on the increasing complexity of the challenges the students face, and the level of independence that is required of the students in solving them. For instance, in the 'Integrating Technology' competency, Bachelor students mainly work with comparatively simple single (discrete) sensors and actuators, while Masters students work with complex networks of (non-discrete) sensors. This increase in complexity requires students to use much more sophisticated methods of mathematical modelling to describe and predict the behaviour of such a system.

Instructors

Two instructors, a **project coach** and a **competency coach**, oversee the students' efforts and progress. A project coach is responsible for coaching the project team with their project. Normally the project coach has a weekly meeting with the project team (or the individual student, if applicable) to discuss progress. In these meetings the design process, the project deliverables, and the team processes are addressed.

The competency coach is responsible for coaching the student on his/her individual competency development. For this the competency coach normally meets with the student every other week to discuss the competency development plan and/or learning goals with the student; to advise the student in how to achieve learning goals and give feedback on progress of student's competency development; and to support the student when writing the self evaluation and helping to formulate the challenges for the next semester.

Each staff member at the Department of Industrial Design also acts as an **expert** to the students, in their area of specialisation. Students can access these experts for selection of the literature they need to solve their problem, guidance in where to find information and for advice on tackling the subject at hand. Often, the experts also give one or several assignments in their area of specialisation.

Formative assessment - feedback.

A student receives feedback on the deliverables, approach and competency development, not only at the completion of assignments and project (final feedback) but also in the course of an activity (interim feedback). Interim feedback may either be given verbally or in writing, final feedback is always in writing. Feedback is provided by someone who is an expert in particular competency (area): e.g., a client, an expert, an assignor, the project coach or competency coach. The feedback is meant to provide the student with a basis for deciding what the next step in competency development should or might be.

Based on the reflection and learning evidence the student together with the competency coach can determine a plan for next assignments and project, or next semester. Questions for the students are: What do I want to learn next? Which competencies am I going to develop? Which project and assignments are suitable means to achieve this? The written feedback provides evidence of competency development and is included in the student's portfolio.

Summative Assessment

The scope of written feedback is a single learning activity such as an assignment and project. The scope of a summative assessment, on the other hand, is student's overall competency development and work completion over a block as a whole. Such an assessment takes places less frequently, i.e., twice a year, at the end of each semester.

Because the Industrial Design student is not tested in the traditional manner, nor do they receive grades for separate learning activities, faculty and students rely upon the portfolio as an instrument to prove competency development. Each semester is concluded with a portfolio-based assessment: Does student's development show enough progress and an adequate level for promotion to the next block? And is the student developing into an industrial design engineer? For each competency area the student has to demonstrate progress, specific knowledge and skills he/she acquired and put to use, and the level that is achieved.

The portfolio, called *IDPortal*, is digital. In his/her electronic portfolio, the student stores work samples, interim and final results (in a *Learning Evidence Folder*) during assignment and project work. Written feedback on the student's work is also stored there. The student documents his/her competency development in a *Portfolio Work Document*. Within the latter, the student can include hyperlinks to pieces of learning evidence, and can reflect on work and what he/she has learned.

The student's reflections on their activities and competency development of a whole block are included in a *Self Evaluation* - again supported by hyperlinks to both types of learning evidence. This bit, together with the corresponding learning evidence, constitutes the assessment part of the portfolio.

In sum, the portfolio serves the following purposes:

- serves as an archive for pieces of work and feedback as learning evidence;
- prompts the student to reflect on these pieces of learning evidence and on competency development;
- demonstrates competency development in terms of progress and level achieved.

It is important to remember is that the portfolio is an assessment instrument, just like examinations are in other courses. So, a student needs to build a convincing portfolio and work on it on a regular basis. Doing a good job in assignments and projects is one thing but if the student is not able to make competency development visible and tangible in the portfolio then it is very difficult to assess the student.

Initial program evaluation

The department of Industrial Design at the TU Eindhoven has been set up five years ago, and the very first students are expected to graduate early 2007. So we cannot yet give a substantial evaluation of the complete, 5-year program.

What we can see is that the TU/e Bachelors diploma does provide the students with enough knowledge and skills to enter the labour market as junior designers. And the third-year internship students have demonstrated a considerable quality in their work. They are valued as being very mature and independent-minded junior designers, remarkably flexible and resourceful in tackling the design challenges that come their way.

NTNU: *Norges teknisk-naturvitenskapelige universitet*, Trondheim, Norway

The Industrial Design Engineering Program (MsSc.)

Johannes Sigurjonsson

The Department of Product Design was established a little over a decade ago (1994). The Industrial Design Engineering degree program, one of two degree programs offered by the department, is a five year, 10 semester program leading to a MsSc. degree. The other program is a two year master in Industrial Design Engineering, practically identical to the two last years of the five year program. To enter the two years program students are required to have similar background as the first three years. In practice this means students with a BSc. degree from the Engineering College in Østfold or at least three years from programs like IDE at TU_Delft.

The general policy is of NTNU is to keep the MSc. programs is engineering and architecture as five years blocks, but presumably this will change within the next five years following the Bologna process. NTNU has recently established several two years (international) master programs which recruit students with three years of studies from other programs. Examples of this are the programs in Entrepreneurship and Industrial Ecology. In particular the first one, already draws several students from our IDE program.

The IDE program(s) is currently not defined as an International program but several central courses are taught in English and integrating foreign exchange students into the program has not been problematic. The number and quality of “English” courses is growing, and the goal is to make all courses in the fourth and fifth year of the master program “English” within the end of 2007. This is in accordance with the general strategy of the Faculty of Engineering Science and Technology.

The department has its own building with workshops and workspaces for students. It's faculty currently consists of seven professors/associate professors. Other staff members include some half dozen Ph.D. students, several post-doc researchers and three engineers who provide support in the workshops and information technology. The vision for the department is to maintain a dynamic environment supporting both a professionally based education and research in industrial design. Faculty stress the need for students to develop the ability to empathize with their client and their work, to recognize their responsibility to their profession and society, to think and design creatively and to communicate effectively in the varied contexts of an industrial designer's work.



The department admits between 20 and 25 new students and has granted approximately 20 masters degrees each year. A total of 9 Ph.D. students have pursued their research programs under the guidance of the department since the founding of the department.

The chart below shows the course of study:

Term	Module	Module	Module	Module
10	<i>Master Theses</i>			
9	<i>Elective Topic</i>	<i>PD9 Specialization / Research</i>		
8	<i>Elective Topic</i>	<i>Experts in Team Interdisciplinary Project</i>	<i>Communication & Packaging Design</i>	<i>PD8 Design Strategies</i>
7	<i>Elective Topic</i>	<i>Elective Topic</i>	<i>PD7 Industrial Assignment</i>	
6	<i>Management of Technology</i>	<i>Eco-Design</i>	<i>Applied Modeling (CAD)</i>	<i>PD6 Products and Systems</i>
5	<i>Statistics</i>	<i>Human Computer Interaction</i>	<i>PD5 Mechatronics</i>	
4	<i>Physics</i>	<i>Materials Technology</i>	<i>Man Machine Interaction (Ergonomics)</i>	<i>PD4 Form and Function</i>
3	<i>Mathematics 3</i>	<i>Mechanics 2</i>	<i>Form and Color 2 Design History</i>	<i>PD3 Form, Material, Production process</i>
2	<i>Mathematics 2</i>	<i>Mechanics 1</i>	<i>Form and Color 1</i>	<i>PD 2 Information Technology</i>
1	<i>Mathematics 1</i>	<i>Ex.Phil.</i>	<i>Form and Color 1</i>	<i>PD 1 Introduction</i>

Each term is divided into four course modules (7,5 credits). This makes a nice table but requires some creativity in combining topics into courses of the right size. The right side of the table (shaded) shows courses given or administrated by the Department of Product Design. The introductory courses in mathematics, mechanics etc are general courses shared by practically all students in the engineering programs at NTNU. Ex.Phil. in term 1. is also a general course with introduction to history and theory of science.

Of the four elective topics, two should be from other engineering programs and two from non-engineering programs. Here the students select a variety of topics like; economics and management, psychology, material science; architecture and medical technology. The Experts in Team project in term 8. is an obligatory project for all students at NTNU, where students with different background join forces in a team of 6 persons to attack a given problem field.

The sequence of product design courses ending with a master thesis provides the backbone of the program. See table next page. The product design courses make full use of the facilities available in the department - shops, computer network, meeting areas. The courses are project based and the projects involve both group work in groups from 2 to 5 student and individual assignment. The amount of individual projects is approximately 50%. From term 4. the design projects are related to realistic problems in cooperation with industry. The department therefore has established strong ties with industries representing many different sectors: Bergans, Hydro Aluminium, IKEA, LEGO, Laerdal Medical, Nokia, NSB, Statoil, Volvo to name but a few. Individuals from these

companies propose projects - for masters thesis work, course projects, and research collaboration with faculty and students - and help guide the student in their efforts. Direct communication between students and industry is limited in the beginning, but increases gradually up to the master thesis, which normally is closely linked to a company.

PD 1 An Introduction to design
An introduction to Product Design with emphasis on the designers tools, knowledge and working method through lectures and practical exercises ending with a design project.
PD 2 Information Technology
The student an understanding of information technology and its applications in society, an introduction to the use of information technology in product design, and skills in the use of computer tools for collecting information, presentations, design and construction.
PD 3 Form, Material, Production process.
The course will give the student an understanding of the interaction of product's aesthetics, function, material and process. Training in goal-oriented product design, with three consecutive design projects addressing different materials and production volumes.
PD 4 Form and Function
Introduction to work processes and systems design. Products accommodated to user and market and the interaction between function ergonomics and aesthetics is important. The course will give insight to and exercise in using knowledge of human beings in the development of products. In the design process, the emphasis is on analysis and evaluation according to the user, the operation of the product and its context. The course is coordinated with a parallel course in Human-Machine Interaction/ Introduction to Ergonomics
PD 5 Mechatronics
The purpose of the course is to give an understanding of how mechatronical systems are structured and how they work. Introduction to electromotors and actuators, control systems, pneumatics and hydraulics. A group project in design of a mechatronical system through a combination of mechanical engineering, electronics and system thinking.
PD 6 Products and Systems
Introduction to general aspects of system and logistics in society. Design project addressing a complex system. The course is coordinated with parallel courses in Ecodesign and Advanced Modeling (CAD).
PD 7 Industrial Assignment
Through this course the student will further develop knowledge and skills in realistic product design projects in close cooperation with industry. Seminars and lectures in design methodology. Special emphasis is put on initiating and planning an individual project in collaboration with an industrial company, where the student takes on the responsibility for project management and communication.
PD 8 Design Strategies
Introduction to models and methods for managing projects in design and product development. Strategies for product development aiming at making a profitable product with technology and market possibilities in mind.
PD 9 Specialization/Research
In this course the students dig deeper into theoretical issues related to product design, and they implement and develop this theory through project work. Each student chooses a main direction for the project, and one of the following directions: Aesthetics, Technical Analysis, Interaction Design, Management and Organization (including ecodesign). The course assessment is based 1/3 on a review paper and 2/3 on an experimental project. See papers here: http://www.ivt.ntnu.no/ipd/forskning/artikkel.php
Master theses
The master thesis takes 20 weeks and is an independent project, normally in cooperation with a company or an organization. (95%). The project should primarily fall within one of the following categories. Designproject, Designstrategies or Designtheory.

Examples of master projects from the last three years:

- A new Concept for a Construction Equipment
- Redesign of a cooling vest for laparoscopic chirurgic operation..
- The Aesthetic and Identity of the Staircase
- Development of User Interface for Control Rooms
- Design of an Internet Game for Mathematics
- User Concerns in Factor 4 Dwellings, and Design of a low-energy product.
- Design Strategy in Technology driven Innovation

An overview of the projects and a short summary (in Norwegian) may be found here.

<http://www.ivt.ntnu.no/ipd/fag/Master/Index.html>

Faculty and graduate student staff take on research and development projects in close collaboration with their industrial partners. Project foci include Design Strategies; User/Interaction Design; Sustainable Design, Ethics; Design Methodology with special attention to Aesthetics; Design education and pedagogis; Materials and Design. A total of 9 Ph.D. students have pursued their research programs under the guidance of the department since the founding of the department.

Reflecting the nature of contemporary design activity, the faculty is truly interdisciplinary and benefits from being a part of a “complete” university. In education and research work, the department relies upon active cooperation with other programs and departments.

- Faculty of Architecture and Fine Arts (Form and Color courses, Research cooperation)
- Industrial Ecology (eco-design & other courses, research cooperation)
- Department of Computer and Information Science (HCI, User centered design)
- Department of Interdisciplinary Studies of Culture - Studies of Design, Consumption and Culture (IKON)
- Oasis - the innovation laboratory at NTNU
- Product Development and Materials (Materials, Workshop)
- Faculty of Medicine (Various projects)
- SINTEF (Fisheries and Aquaculture, Technology Management.)

Chalmers University of Technology, Göteborg, Sweden

The Industrial Design Engineering Program

Ulrike Rahe, MariAnne Karlsson

The masters program in Industrial Design Engineering, started in 1999, combines studies in engineering with studies in design and of the interplay between man and technology. It is based on the recognition that those working in the field of design today must have knowledge of people in terms of their physical, mental, emotional and – not least – cultural make-up, and be able to translate this expertise into user-friendly technical solutions - products designed with full regard for humans' capacity to grasp and handle technique safely and efficiently. It is also necessary that graduates know about all stages in the product development process, how these are accomplished with the help of technique, about the contexts in which this technique is applied, and how these factors affect the final design. The ability to handle information technology in a deliberate and conscious fashion is also a main theme of the program.

Students acquire a broad, professional grasp of 'form' in its widest sense, along with a strong technical foundation. Preconditions are provided for learning to handle the physical, cognitive, social and cultural factors involved in people's interaction with artefacts and for mastering product design tasks in practical terms. Knowledge of construction and production techniques is conveyed on a broad scientific and engineering basis in order for students to be able to organize, manage and decide questions relating to technique and construction. The program aims to prepare students for careers in industrial product design and development, with a specific role in, for example, product planning and project management or as a project coordinator. Other career opportunities may be found in academic research and/or education at different levels.

Course content

Instruction in the program relies upon problem based learning and design projects to foster student development of methodical and creative working methods and to advance the knowledge and skills they acquire in other traditional courses - e.g., lectures, course textbooks, and seminars. Project orientation develops students' ability to creatively synthesize aesthetic, communicative (semantic) and ergonomic preferences with technical, social, economic and environmental/ecological requirements in a functional and attractive form. Project tasks of varying extent are included in almost all the courses offered in the program. (See chart, next to last page).

In the **Basic Design** courses, students develop understanding and skills in working with form and color as fundamental creative parameters. Complexity in the tasks assigned rises successively from two-dimensional planning to three-dimensional creation and color setting. The aim is to enable students to handle problems of form and relate these to functional requirements. By means of *two-dimensional* tasks students engage the principles of systematic design and acquire an understanding of how and why we experience form and the potential of two-dimensional form transformations. Through working with *colors*, students gain an understanding of their significance in the visual conveyance of information. The relativity and contrast phenomenon of colors and their powers of expression together provide a basis for creative training at abstract levels.

The course on **Industrial Design Engineering Method** deals with the various stages of the design process and with the content, scope and problems of development work. Students learn how to identify and solve design problems and to evaluate ideas and solutions. The project work focuses on user aspects and product-user compatibility.

The **Design Ergonomics** course provides students with an overall view of human factors susceptible to design and which are essential for human beings' performance, health, comfort and safety. Knowledge of anatomy, physical ergonomics, anthropometry, biological variation and biomechanics is related to cognitive ergonomics and an understanding of perception, information processing and decision-making. The project offers students the chance to design technical products and systems with full regard paid to the user's specific conditions and limitations, demands and desires.

In the course **Design and Human Factors** instruction is given in basic principles and methods for identifying, analyzing and describing preferences of customers/users with regard to a product's function and quality. Students learn to chart the needs and requirements of users and to analyze both qualitative and quantitative data they have obtained through both interviews and observations; a user-friendly design proposal is developed. In the connected project work, students are trained to deal with concrete design and product development problems having to do with the user interface. Design and User Compatibility is the main topic for the project, based on an analysis of a problem area selected by the student; this provides the starting point for further study and the development of proposals for an improved solution to the problem. Having students select a *non-functioning* product use and then formulate a way to improve man/machine ensures that their work is problem, rather than product, oriented. In this way, entirely new innovative product solutions can be generated.

In **Product Semiotics**, students' creative competencies for assessing the relationship between the functions and effects of design elements and the product's "message" are developed through studies of design transformations, associations, transitions between differing materials and design elements, and with the help of an experimental, investigative working method. The project aims to develop the student's ability to analyse and design products with emphasis on its semiotic and design-aesthetic aspects.

Visualization and Computer Aided Modeling deal with promoting the use of computers in the design process. Students' abilities to work with virtual product representations is developed through practice and in the context of project applications. Photo-realistic images of products are made both in the studio and outdoors. The results can be either stills, exploded presentations, or some other form in which visual movement and animation play a major part.

The Industrial Design Engineering Bachelor Thesis Project addresses the complete conceptual design and construction development process from its preliminary stages – product planning, specification and conception – to the final stages of materials selection, construction and manufacture. Students acquire a broadened understanding of what development work entails, its overall extent and problems encountered. The project work gives students the opportunity to apply skills learned in practice since it is linked to real working conditions. The experience stimulates the development of a critical and reflective approach to the product design and development process.

Master Program

The first year is intended to provide the students with a common platform for the further studies. This means that the major part of the courses is compulsory.

Courses in industrial design-related subjects and in engineering design-related subjects are to be studied in parallel in order to comply with the overall aim of the master's program.

The second year is intended to provide the student with an opportunity to develop further knowledge in industrial design engineering. The student may choose between a narrow or a broad profile.

A broad profile implies a choice of courses in engineering design related courses and/or in industrial design related courses and/or in courses that concern managerial issues. A narrow profile implies a specialization. The master program offers two specializations: in Product Design (Engineering) and in Human Factors (Engineering).

The number of elective courses will then be more limited. Product Design Engineering means a focus on aesthetic; formal; and semantic design problems while Human Factors

Engineering stands for problems associated with designing the interaction between users and technical products/systems. Additionally, the student may choose a specialization, preparing him or her for post-graduate training and research.

A master thesis project will complete the program. The master thesis/diploma work should mirror the fundamental program idea, i.e., the integration of engineering design and industrial design. If the student has chosen a specialization, the master's thesis/diploma work should in addition to the overall aim demonstrate the student's specialization, i.e., in Product Design Engineering or in Human Factors Engineering.

Master Course content

The Master program encompasses compulsory courses (30 credits); elective courses (30 credits); and an obligatory Master thesis (of at least 20 credits). The compulsory courses include the following:

Industrial Design Engineering: Theory and Methodology (5 credits) is an initial course in Industrial Design Engineering: Theory and Methodology is to provide an important context for the courses within the master's programme.

Industrial Design Engineering: Project Part A and Industrial Design Engineering: Project Part B (5 + 5 credits) The Industrial Design Engineering Project courses, A and B (5+5 credits) are intended to create an arena for addressing a design problem that requires the integration and application of both design and engineering knowledge and skills. The courses will allow the student to work with a design problem from problem analysis, through idea and concept development, through to a feasible solution taking account of technical, ergonomic, communicative, and economic aspects.

Computer supported modelling (5 credits) will help the students develop further knowledge in using CAD tools for modelling and visualization, and in managing the interfaces between modelling and prototyping, construction, production.

The course **Visual Brand Identity & Market Analysis (5 credits)** addresses the issue of visual identity from a branding and product design perspective. Also market strategies product differentiation and positioning, customer segmentation, and design management are covered. In the project work, starting from a visual brand perspective and the preconditions of the market, students apply “semantic transformation” as a means to ensure that the message conveyed by the product creates the desired brand image.

Compulsory courses for the specialization in **Product Design Engineering** are:

The course **Advanced Product Form I (5 credits)** serves an introduction to strategic design and design aesthetics, within the context of a three-dimensional product design process. The course concerns formal aesthetics, concepts, methods and tools. The Students gain an appreciation of those aspects of form design and obtain further understanding of product semiotic theory and method. and skills to handle these tools.

Advanced Product Form II. (5 credits) will enable the students to develop deeper knowledge of strategic design and formal aesthetics and knowledge to apply this knowledge in three dimensional product development. The course project consists of a design-oriented product design application in which solutions are developed to satisfy aesthetic, semiotic and functional criteria.

Compulsory courses for the specialization in **Human Factors Engineering** include:

The course **Cognitive Ergonomics (5 credits)** intends for the students to develop further knowledge of the relation and interaction between the design of technical artefacts and human beings from a cognitive and emotional perspective.

The course **Product Ergonomics (5 credits)** intends for the students to develop further knowledge of the interplay between the properties of technical artefacts and the physical properties of human beings. The course addresses some of the methods and tools that can be used to analyse different design solutions from an anthropometric and physiological perspective.

Honors and Highlights

The *Association of Swedish Engineering Industries* is the trade and employers' organization for Sweden's most important companies. To better exploit young people's interest in technology they are investing 25 million SEK over the next five years in order to focus greater attention on technical subjects and technical education. The measures to be taken include an award entitled “Technical training of the year” to be given for especially successful training initiatives at University of Technology level. This year's prize, ‘Högskolan för 2006’, has been awarded to the Chalmers Industrial Design Engineering Programme, which receives a million SEK to further develop the course and an additional 500,000 for student stipends.

Four design prizes have been won by our students during the past year,

- the best examination project in ergonomics from all the Nordic countries,
- The Red Dot Award in Product Design,
- The Swedish Aluminium Packaging Design Award 2005 in all three categories,
- and the bronze prize in Innovation Design.

Program Plans

Program Plan Industrial Design Engineering, Bachelor level - Year 1.

Quarter 1 - Year 1	Quarter 2	Quarter 3	Quarter 4
Introductory Course in Mathematics, (5)	Calculus in One Variable, (4 credits)	Linear Algebra, (4)	Calculus in several variables, (4 credits)
Introduction to Industrial Design Engineering, (3 credits)	Computer Aided Modeling, (5 credits)		Product Semiotics, (4 credits)
	Mathematical Software, (3 credits)		
	Basic Design 1, (4 credits)		
2D and 3D Concept Visualization, (4 credits)			

Quarter 1- Year 2	Quarter 2	Quarter 3	Quarter 4
Design Ergonomics, (5 credits)	Mechanics, (5 credits)	Strength of Materials, (5 credits)	Materials Technology, (5 credits)
	Product Requirements Eng. (4)		
Design and Human Factors, (5 credits)			Fluid mechanics, (4 credits)
Basic Design 2, (4 credits)			
Visualization, (3 credits)			

Quarter 1- Year 3	Quarter 2	Quarter 3	Quarter 4
Environmental Technology - Sustainable Development, (5)	Manufacturing Engineering, (5)	Industrial Design Engineering Bachelor Thesis Project (10 credits)	
Machine Elements, (5 credits)	Elective Course, (5 credits)	Elective Course, (5 credits)	Mathematical Statistics, (5 credits)

Program Plan Industrial Design Engineering, Master level

Quarter 1- Year 4	Quarter 2	Quarter 3	Quarter 4
Industrial Design Engineering – theory and methodology (5 credits)	Visual Brand Identity & Market Analysis (5 credits)	Industrial Design Engineering Project Part A (5 credits)	Industrial Design Engineering Project Part B (5 credits)
Computer Supported Modelling (5 credits)	Elective Course (5 credits)	Advanced Product Form I** or Elective Course, (5 credits)	Advanced Product Form II** or Elective Course, (5 credits)

Quarter 1- Year 5	Quarter 2	Quarter 3	Quarter 4
Cognitive Ergonomics* or Elective Course (5 credits)	Product Ergonomics* or Elective Course (5 credits)	Industrial Design Engineering Master Thesis Project (20 credits)	
Elective Course (5 credits)	Elective Course (5 credits)		

* obligatory for Master specialization in Human Factors Engineering

** obligatory for Master specialization in Product Design Engineering

- Elective courses (5 credits each) in the Master Program preliminarily are
- Integrated product and project management
- Product development
- Interaction design
- Computer aided modeling, advanced course
- Industrial marketing
- Road vehicle aerodynamic design
- Integrated product and project management
- Visual simulation for product development
- Environmentally adapted product development and manufacture
- Advanced design materials
- Life cycle assessment
- Basic Design 3

The National Polytechnical Institute of Grenoble The industrial & design engineering program

Dominique Vinck, Eric Blanco

The National Polytechnical Institute of Grenoble, France, (INP-G), offers ten engineering tracks, each leading to a master's degree after three years of study. That these programs only require six semesters of study is made possible thanks to the recruitment of students having at least 2 years of basic sciences (mainly mathematics and physics). Classes are mainly given in French.

In the present paper, we focus on one sub-track, Integrated Design and Manufacturing, within the Industrial Engineering track. The Industrial Engineering program focuses on the optimization of industrial processes and innovation. It aims to develop students' all around understanding of business performance. Three domains are emphasized - the engineering sciences, economics and management, and the social sciences. The objectives are: i) to train engineers in the issues surrounding the business world; and ii) to train multi-skilled engineers who can take a broad view of the business, its organization, resources and its dynamics. Graduates are expected to have the capacity to view a business as an integrated whole and to fuse a technical approach to problems with an understanding of organizational issues.

Within this framework, the teaching focuses on a few main priorities: the principle industrial engineering skills, including the management and organization of production, logistics supply-chain management and its optimization, and an integrated approach to product and service development, quality, consultancy and auditing. The sub-track aims to train engineers to take an integrated approach to product and service development.

Compared to a more traditional engineering design program, e.g., in mechanical engineering, one that stresses discipline specific learning and skills such as fluid and solid mechanics and the simulation and modeling tools that are used in these subjects but pays only limited attention to organizational aspects, the integrated design and manufacturing program is quite original within the framework of industrial engineering.

One primary feature contributing to the program's uniqueness is that the Industrial Engineering school belongs to both the Polytechnic Institute and to the Grenoble's University of Social Sciences. Students learn about industrial innovation and approaches to the optimization of industrial processes from a multidisciplinary faculty, and with the energetic involvement of local industry. They learn to combine a technical approach with social/economic and organizational understanding that goes beyond instrumental methods in developing an in-depth understanding of the multi-dimensional context of business activity, its modes of organization and its changing dynamics.

The underlying philosophical basis of the curriculum derives from the observation that industrial performance depends on the efficient working of a complex system of diverse services - a system which requires the management of multiple interfaces by a collection of heterogeneous actors (located both inside and outside the firm). Services include product design (including user-centred design and marketing), industrialization, supply chain management (both global and local), pro-

duction optimization, information system management, and negotiation. All these activities require serious attention to social, economic, and organizational as well as technical issues.

The three year program, consisting of 6 semesters, starts off with an introductory week intended to break the students away from their previous training in mathematics and physics. Through films, exposure to the fundamentals of new disciplines (like sociology and economics), role games, and so on, students are introduced to industrial and societal problems.

The chart below shows the curriculum requirements, each row one of the six semesters.¹

		ECT POINTS										
		0	5	10	15	20	25	30				
SEMESTER	1	Introduction		Engineering Science - Basics			Social Science - Basics			Foreign Languages		Industry Internship
	2	Industrial Science			Computer Science Operations Research		Eco. Mgmt.	Economics of the Firm - Basics			Lang..	
	3	Production Quality Management			Product design and Corporate Finance			Info. sys. Networks	Elective.. (3)	Language..		
	4	Supply Chain Design, Scheduling		Industrialization Marktnng, Commerce		Change Management & Field Study			In-depth Elective (4)	Language		
	5	Mgmt. Supply Chain	Elec. (5-1)	Design & Innovation	Elec. (5-2)	Elec. (5-3)	Economic Vision & Strategy	Elec. (5-4)	Law, Society, the Firm	In-depth Elective (5-5)	Language	
	6	Further in-depth specialized study and 5 month project in industry										

- (3) Options are Biotechnology, Energy, Intro to Micro-technology, Networks and telecommunication.
- (4) Options are Multicriterion decision making, Supply Chain coordination, Creativity & Innovation, Optimization and Simulation of Production Systems, Systems and Data Bases, Web and Informatics.
- (5-1) Logistics strategy case study, production planning & inventory mgmt, Demand forecast & planning, Decision making in stochastic systems.
- (5-2) Green design, Integration of users into product and service design processes, Management of innovation.
- (5-3) Collaborative design, AI & knowledge management, Product life cycle management.
- (5-4) Management of the environment, Total quality & management systems, Forecasting & strategic intelligence, Worker skill, safety and health.
- (5-5) Entrepreneurship, Project evaluation, The global firm, Research, Industrial Information Systems

In the **first semester**, the block, *Social Science - Basics* includes a 3.5 ECTS course titled “Sociology and History of Science, Technology and Enterprise”. Its objectives are i) to dispel the folk theories students bring to class about science, technology, organizations and enterprise; ii) to bring to the fore the analysis of organizations as they actually function and to show the importance of social norms and regulations in shaping the production and innovation process; iii) to teach concepts and analytical approaches useful in explaining the dynamics of innovation, knowledge production, and the organization of work.

In one exercise, students focus on a scientific or technical controversy, where they identify the issue, follow it through, and analyze the debate. The aim of this 4 month exercise is to confront these future engineers with a situation in which a political, ethical, social and economic controversy is complicated by unstable scientific knowledge.

The class develops approaches to the organization of work within the context of socio-technical and political systems, paying specific attention to collective action, negotiation and the development of professional identity through work.

At the end of the first semester, the students do a one-month internship in industry as a simple operator. This provides them with an opportunity for situated learning about industrial activity and organizational dynamics. Prior to entering the firm, students study the elements of ergonomics (knowledge and description of the work), research methodologies (observation of technical, sociological and ergonomic aspects) and socio-technical analysis. After completing the internship, every student has to write a report describing his or her work experience within the firm. They then, in a group, compare their experiences and observation framed by a common theme, e.g. work conflicts, communication problems, degree of involvement at work, IT introduction. They together write a report where they have to put to use both analytical tools and field data.

The **second semester** is structured in accord with the same logic. Students pursuing the sub track “Integrated Design and manufacturing” are introduced to design within a basic economics course titled “Industrial Engineering of a Project - Part 1”. They learn mechanical modeling, not from a materials perspective, but from a more general, engineering perspective. A multidisciplinary teaching staff (Mechanics, Economics, Marketing) runs the course. Students, in groups of 10 to 12, analyze an existing product with respect to four dimensions - the product (market analysis, the competition, functional analysis, key technologies; its fabrication (processes and organization); production management; and supply chain architecture and management.

The primary objective is for students to be able to understand and describe what it takes to design and develop a new product. In addition, students learn to work on a relatively large team project. They choose a project leader, define a budget, in terms of man hours which includes a budget of 3 hours for gathering advice from an expert. The project leader is responsible for the planning, the coordination of the group members work, and for meeting the schedule for deliverables.

The project team is divided into four “approach groups”; each group chooses a spokes-person. The four spoke-persons have to report at specific tutorial sessions. Students have also to visit a hosting enterprise to describe their project. Every project team is tutored by two professors - one in engi-

1. For a more detailed description, see http://www.ensgi.inpg.fr/63882638/0/fiche___pagelibre/

neering science, the other in the social sciences. Students benefit from regular debriefings during which they discuss the difficulties encountered in project management. The “approach groups” benefit also from session devoted to knowledge sharing, methodological support, and comparative analysis of the different projects. Finally the group has to propose an innovation to improve the competitiveness of the host company. They present and defend their proposal in front of a jury teachers and of industrialists. This kind of exercise is representative of the interdisciplinary approach and active learning practices the teaching staff has developed over the past 15 years, aiming to provide students with a global, multidimensional and integrated approach to product design, development and manufacturing.

During the **second year (third and fourth semesters)**, students engage in more industrial engineering study, including the realization of an industrial plan, the study of technology, and do a new internship as an associate engineer. The product design course aims to develop the students understanding of the complete design process. Students acquire a few basic skills enabling them to interact and communicate with the relevant experts. While not designers by themselves alone, they gather experience from working inside a project team.

In a “Product/process Design” class within the *Product design and Corporate Finance* block students study the numerical chain in product-process design (CAD/CAM), in order to specify the product definition file and fabrication technologies. A “Design Project for New Products” course within the same block is dedicated to the creation of a new product and to its economical validation (including a marketing study). Active learning is stressed.

In the fourth semester, several specific classes are dedicated to engineering design. “Industrialization, industrial launch and marketing” trains engineers to develop a product’s industrial file which defines the production process, metrology and tolerances and includes the definition of a commercial strategy (marketing plan, product policy, price policy, communication policy, distribution policy, planning and control).

A class “Organizational Design and Change Management” (sociology and ergonomics) aims to develop a student’s capacity for diagnosing the performance of an organization. Students study how to assess effective conditions for organizational change and learning. They have to think about new industrial trends; e.g., intensification of the competition inside and between firms, flexibility, just in time manufacturing, innovation, performance evaluation, knowledge management, and also the practice of ergonomic intervention for the design of new organizations of work.

The “Creativity and Innovation” class aims to involve engineers in the creative process: Research of new ideas, their consolidation, the writing of specifications, the management of intellectual property (patents making) are all addressed. The main objective of this program is to develop practical skills for dealing with the challenge of innovating, coming up with new products, and learning how to handle problems encountered through the use of various creativity methods, e.g., the *TRIZ* method.

A very interesting assignment, practical in nature, requires students in groups of three to undertake an industrial mission consisting of 100 hours in industry; one day a week for 8 weeks, plus one full additional week at the end. Students have to organize themselves to solve an industrial problem and to manage the corresponding project in real industrial contexts, e.g., they must attend to cost issues, scheduling delays, people relations. They periodically report to an industrial tutor and to

two faculty - one in the engineering sciences, the other in social sciences. The two professors also make two site visits with the students.

The **third and last year** is dedicated to deepening the student's knowledge in different special domains and to the realization of a 5-months project inside industry.

In the **fifth semester**, in a class "Product Design and Development" within the *Design & Innovation* block, students study the principles of organization and management of the design process within the firm. Six themes, focusing on theory and company's practices, are explored: Product Design Process and Organization, Product Architecture, Product Life Cycle Management, System Engineering, Product/process Integration, and Design for Innovation.

The course "Dynamics of Innovation" within the same block takes a social science approach and introduces students to selected STS approaches to issues e.g., Actor-Network Theory.

The students also have the opportunity to learn about "Green design" - one of the options within the block Electives (5-2). Or they can choose to study methods for engaging users in the design process, methods such as user-centred design, scenario-based design, direct user involvement, marketing centered approach, sociology of use, and ergonomics.

"Collaborative Design" within the block Elective (5-3) advances an approach for establishing and improving cooperation among firms: students study collaborative work, supplier integration, computer supported cooperative work, but also engage the students game-like exercises that have them role play negotiation between firms. The "Product life cycle management" class within this same block introduces tools used for change and versions management, document sharing, nomenclature, multi-views, diversity management, communications.

Finally, at the end of their training, these neophyte engineers will spend 40 weeks in an industry, first to observe how it functions, then to manage projects. Note that, 70% of the students will have an international experience - either inside foreign universities or through industrial practices).