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MECHANICAL ENGINEERING CURRICULUM AT DTU AND THE APPLICATION OF CDIO IN FIRST YEAR COURSES.

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ABSTRACT

In the last couple of years, DTU has been through the same major changes in the structure of the educational system as many other of the European universities have. The implementation of the Bologna declaration results in the cancellation of the traditional 5 years Masters degree and a build-up of new 3 years Bachelors and 2 years Masters Educations. Though special attention has been paid to not making too many drastic changes, a lot of effort has gone into a re-thinking of study plans, goals, possibilities and inappropriate situations.

In the mechanical engineering area the Department of Manufacturing Engineering and Management and the Department of Mechanical Engineering deliver the technical courses for the Bachelor education (called Production and Engineering Design, P&E). In cooperation the two departments gives an introductory 'Engineering Work' course with much emphasis on the CDIO philosophy. This course in particular but also the design of the study plan will be described in this paper as will an ongoing effort on evaluating the current curriculum with improvements in mind.

A part of this evaluation of the curriculum will involve an analysis of first year courses among some of the universities participating in the CDIO initiative and comparing this with the goals set and results achieved at DTU. It should be mentioned here, that traditionally, the students coming from the Danish high school system have an almost lifelong experience in some of the professional, personal and interpersonal CDIO skills, group work, team work, report writing, communication etc. To a large extend this reduces the effort that we usually put directly into teaching those topics and allow us to put more emphasis on developing their technical skills and only make sure that their proficiency in personal and professional skills are maintained and developed to a reasonable extend.

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INTRODUCTION

Until recently, the educations at DTU could structurally be divided into a 3.5 years Bachelor of Engineering program with emphasis on practical applications and the goal to educate candidates that could handle daily operations in industry, and a 5 years Master of Science in Engineering program that focused on a research based education aiming at preparing the candidates to take active part in research and development in companies as well as in research institutions.

The structure of the DTU educational program is relatively modularized, that is, each subject is taught in a 5 or 10 credit course; and the relations to other courses are either prerequisite courses or the course being a prerequisite for other courses. To some extent, those links are only vaguely maintained. In particular, when courses changes drastically (like our courses in mathematics have done), not all teachers in subsequent courses may notice the changes until some students make him aware of it!

Due to the difference in goals the two groups of students have been kept apart as have the teachers. Another difference between the two educations was that in the Bachelor program, the students had almost no elective courses (in total corresponding to less than half a year of study), whereas the Master students could finalize with less than two study years of compulsory courses. In order to obtain a degree with a specialization, though, some stronger requirements must be fulfilled but in total that typically left the student with almost two years of study on fully elective courses.

The annual calendar at DTU is divided into two semesters (fall and spring). Each semester is divided into a 13 weeks lecturing period, a 2-3 weeks exam period, and a 3 week period with one course running “whole day” for all three weeks. This division has always been important in order to maintain a balance between theoretical and practical courses. Though we do have experimental courses during the 13 weeks period, most of the 3 weeks courses have built in a high degree of practical experiments either in the workshop or in the computer lab. Over the years, budget cuts and cuts in the number of courses that we can give, have been relatively hard on the number of practical courses available. They are the most expensive and they are the most time consuming courses for the teachers. We are though aware of that it is a special brand for our candidates (both Bachelors and Masters), that they have had some practical courses during their time of study. Admittedly though, the students do not have as much practical experience that we would declare the educations to be CDIO educations.

Both the Bachelor program and the Master program were divided into different specializations (chemical-, civil-, electrical-, mechanical-, and etc. engineering, to mention a few). There were all in all 7 Bachelor programs; for the Master program there was 12 different intake programs and 16 outlet programs. Due to the implementation of the Bologna declaration this will be changed over the coming years in a dynamic process. This has already begun with the students starting at DTU in September 2004.

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THE DTU (3+2) CURRICULLUM.

The process of changing the DTU studies from the previously described structure into a structure in accordance with the intentions in the Bologna declaration has been long and tough. It is not easy to split up a 5 year rounded study plan into 2 complete and final studies, which complement one another. Opening both of those such that the initial Bachelor serves as a good (international) foundation for taking the Master abroad, and similarly accepting foreign students into our own Master programs with the mixture of prerequisites that they have – that has been and will be a major challenge. At the same time, it is mandatory to maintain the quality of the DTU candidates, and this has forced us to put much more focus on the professional progress that our students are making during their studies – this attention might be beneficial for both students and faculty.

One of the first decisions to make was whether DTU should maintain one or two Bachelor studies; i.e. if the original (professional) Bachelor of Engineering could serve both as the entrance education to the Master study and as rounded education for an industry career or if we should have two separate Bachelor studies. It was important for DTU to maintain 3.5 years engineering education leading directly to a professional career in industry and this education serves by no means also the purpose of being a foundation for finalizing with a Masters degree within 5 years of study. Thus we had to build a new Bachelor of Science education lasting 3 years, which is not giving competences to fulfill a job in industry but serves as a solid foundation for continued studies either at DTU or elsewhere. It is important to emphasize that a student having passed the Bachelor of Science with the smallest possible margin is qualified to continue studying on our Master program – this requires some explicit descriptions of competences achieved during the Bachelor program and writing up this is now in progress. Unless explicitly stated otherwise a reference to a Bachelor program is always a reference to the Bachelor of Science program immediately preceding the Master program.

Currently, we have with some 12 different curricula's on the Bachelor program. Each of these is a separate education and the students will have to sign up for a specific program and switching to another program can be complicated. 'In the old days' switching between the different studies offered was relatively easy, since the students formally (only) had signed up at DTU. In order to avoid the different curricula to diverge some structural rules have been set up. In short, they can be described as follows: 3 years of study has the equivalence of 180 credits. The types of courses that students take are divided into the following four categories: Scientific basis courses (mathematics, physics, etc.), technology courses (they determine what kind of Bachelor it is), projects and general courses, and finally the elective courses. It has been a cornerstone to the structure of the whole study plan, that each of the four groups is 45 credits (25%). This illustrated in figure 1.

Basic Scientific Courses 1 45 credits	Technology Courses 2 45 credits
Projects and General Course 3 45 credits	Elective Courses 4 45 credits

Figure 1: General structure of all the BSc. educations at DTU.

Between the different Bachelor programs there could be variations on which courses are relevant as the scientific basis, but in general this group has 20 to 25 credits mathematics, 10 to

15 credits physics, some chemistry, some statistics or similar courses. A typical set-up for the technological courses is to require 45 credits passed from a list of courses 60 credits long. The elective courses cannot be chosen fully at random; it is necessary for the student to spend some of these credits on prerequisite courses to courses appearing in the following Master program (since each Bachelor program can serve as basis for several Master programs, this is not making it easier for the students!). We highly recommend our students to plan their studies one to two years ahead. Typically, the fourth group, projects and general courses contain the following: a 10 credit project on the fourth semester, a 15 credit final project on the sixth semester, a 10 credit course on 'Engineering work', a 5 credit programming course, and a 5 credit course on engineering science and history.

A similar frame for re-defining our Master programs will be set up. This is a work in progress and it is expected to be finished by the end of the year. With 2 years and 120 credits available, each of the four groups will be 30 credits. Superfluous courses taken during the Bachelor will be transferred (if possible) to the Master study. It is allowed to take more courses than required!

At DTU, it is important to maintain a relatively high proportion of elective courses in our student's curriculum, since we believe that students learn more when they study from interest and not from obligation. It is also important to mention, that with a Danish industry consisting mostly of SMEs (small or mid-sized enterprises), it is important that for instance mechanical engineers cover rather different fields but have a common foundation. In a curriculum with only few elective courses the progress can be maintained in a compulsory part. With over 25% elective courses in a student's curriculum it is important to ensure a continued progress during the course of their studies and to develop some tools that can be used by the students in the process of making their own study plan. It is in our view important to maintain a certain balance between elective courses and a reasonable progress in the studies.

Finally, the first year of study is planned fully with only room for letting the students select one 5-credit course (either an elective course or a technological course) on the second semester. In subsequent semesters the students are supposed to administer their own plan of study more freely. During their first year, the students will have an exercise on how to make their own plan of study primarily based on some study plan examples. To quote a colleague from industry: 'How can you develop a project leader responsible for a billion dollar project from a person (student) not being able to take the responsibility for his/her own study'.

At DTU, it is a management decision that more and more of our professional Bachelor of Engineering educations should be given as CDIO educations. They are well suited for this since they are required to have a major practical content in combination with theoretical issues and they have a relatively fixed plan of study (few elective courses). Our Bachelor of Science educations will contain courses designed after CDIO principles but at the moment we have no intentions of fully exploiting the CDIO concept. The primary reason is our belief in a high percentage of elective courses and this makes it somewhat difficult to tailor the progression in the education.

PRODUCTION AND ENGINEERING DESIGN (P&E) – THE STUDY PLAN

It was a management decision that the name of our Bachelor in mechanical engineering should not be ‘Mechanical Engineering’. The reason being, that that title had a scent of grease and wrench despite it described the content completely. Instead the Danish title ‘Produktion og Konstruktion’ (translated into ‘Production and Engineering Design’ (P&E)) was chosen. Whether there is any connection at all is doubtful, but more than a 60% increase in applicants was detected immediately after the change of name as well as a considerable higher percentage of female students. There can be many other reasons for this increase in interest but an increased marketing effort is definitely not one of them!

Referring to the numbering in Figure 1 a short outline of the content of the Bachelor in P&E can be given as follows:

1. Advanced Engineering Mathematics 1 (20 credits), Physics 1 (10 credits), and Fundamental Chemistry (5 credits) are compulsory and the students must choose two of the following four 5 credit courses: Advanced Engineering Mathematics 2, Physics 2, Introduction to Statistics, or Probability Theory.

2. 45 credits from the following list of courses: Process Technology, Materials Science, Production Technology (Workshop Training), Production Technology (Fundamentals), Introduction to Production and Operations Management, Basic Fluid Mechanics, Principles of Naval Architecture and Offshore Engineering 1, Fundamentals of Engineering Thermodynamics, Strength of Materials 1, Strength of Materials 2, and Engineering Design. Introduction to Production and Operations Management is a 10-credit course; the other courses give 5 credits each.

3. Projects and general courses: There are two projects to be carried out in this study: a 10-credit (4th semester) project and a final (6th semester) 15 credit Bachelor project. Further, this group contains the Engineering Work course, a 5-credit Programming course, and a 5-credit course on engineering technology and history.

4. The elective courses can be chosen more or less freely from the whole DTU course catalogue (900+ courses), but we recommend the students to study some sample study plans (see four examples of study plans in the appendix) in order to be inspired for their own selection. In particular during the first year, there are very few elective courses to choose between.

We believe, that it is important that the students learn to select between a large variety of courses in order to build the competences that are most essential to them as individuals.

A student signing up for the P&E Bachelor program is automatically enrolled in the first semester courses Mathematics 1 (10 credits), Physics 1 (5 credits), Engineering Work (10 credits), and Production Technology – Exercises (5 credits). Both the math course and the physics course are taught for a whole year with a mixture of lectures, group work, project work, and homework. The evaluation of both courses will be based on elements from project work, homework and traditional written exams taken during the year. The course Engineering Work is described in more details in the next chapter. Production Technology (Workshop Training) is a 3 weeks course where the students learn and try different machining processes in practice; hands on experience.

In the second semester Mathematics 1 (10 credits) and Physics 1 (5 credits) are continued. Production Technology – Theory (5 credits) puts the exercises into perspective and in a 'Strength of materials' (5 credits) course the students will learn some of the basic mechanical engineering competences. We leave it up to the students to decide if the last 5 credits should be used on Material Science, Basic Economy, or maybe something very different.

Looking at the different study plans in the appendix it is obvious that the resulting qualifications from either of them are very different; this is intentionally. To some extent, there will be a common overlap of courses, and it is the intention that this overlap generates a common knowledge and language of the candidates. It should be noticed though, that this is a new study plan and so far we have more expectations to it than experiences with it.

ENGINEERING WORK – A FIRST SEMESTER CDIO COURSE

There are multiple purposes with the first semester course Engineering Work. The principal goal is that it should give the students a very clear impression of what kind of working environment they can expect when they have finalized their studies. Secondly, they should learn some basic technical competences (we try to establish the students within the technical/professional domain of Mechanical Engineering (vocabulary, how do things work, machine elements, jobs, etc.)), and thirdly it should contain activities that integrate the students professionally and socially. It is our belief, that though the students expect to find a lot of mathematics, physics, and other basic sciences on their first semester in order to prepare for the remaining part of their studies, a very different course closely related to their expectations for a coming profession can ease the starting pain.

The Engineering Work course appears on each of the Bachelor lines but most of them are different. Our version of the course has several CDIO elements included but it does not strictly follow the CDIO recipe; the content of the course can shortly be described as follows:

1. CAD, drafting, sketching, animation (40%)
2. Disassemble and assemble a lawn mover with a four stoke engine (20%)
3. Sketch and analyze different parts and functionalities of the engine (10%)
4. Product economy and product enhancement (10%)
5. Engineer lectures, excursions, engineering history, etc. (10%)
6. Group work, report writing, socializing, study plan activities (10%)

The percentage indicates the weight of that activity, time wise. Comments on the different activities follow below.

It is a main objective of this course to teach the students to express themselves using drawings and sketches. Most of our students have not made any sketches at all since they were 10 years old. Being able to read and to some extend to make production drawings is important. As a CAD tool we use Pro/E. In this system it is possible both to produce feature-based models (ready for generating CNC machining codes) and to connect parts and animate mechanisms.

In groups of four the students get a lawn mover with a four-stroke gasoline engine. The students start the engine for control. Then they empty the machine for oil and gasoline before they begin to disassemble everything including the engine. They should list all components and keep track of all pieces in plastic bags. Some operations require special tools – they learn how to use those. The students are asked to guess (qualified) on how the different components are manufactured and from which materials; what are the requirements to tolerances, strength, hardness, and surface roughness. When opened, they should describe the functioning of different mechanisms and some of the processes taking place when operating. This is essentially reverse engineering – or Conceiving. In figure 2, there are some photos taken during last semester.

A separate task is the evaluation of the product economy; what are the costs associated with the production of the different parts of the lawn mover? How does this relate to the product price in the store? How much is spent on transportation? How much man time can be used on the production of the engine? Etc. A Design exercise is introduced by asking the students to extend the functionality of the lawn mover (add-ons for sweeping leafs of the garden, moving snow off the walk way, etc.), but it was not Implemented. The assembly of the lawn mover could be seen as some kind of Implementation, and the students are required to make the engine run again (Operate) before they are finished.

Parallel to the disassembly of the lawn mover, theory lessons are given in product analysis methodology. The product analysis methodology is a framework giving the students a common way of describing products. A product may be described by:

- its parts (crankshaft, connecting rod, piston, cylinder etc.)
- super-system (the lawn mover) and sub-systems(the engine, the air filter, etc.)
- the task that it performs (cutting grass)
- the operator interface (starter, speed control, brake)
- the internal process (four stroke engine)
- etc.

The students do not know the professional designation of many of the components and machine elements, but the product analysis methodology gives the students a basic vocabulary so that they can describe a product in a professional way.

Figure 2: Students disassembling a lawn mover engine

During the course there are some lectures made by younger or older engineers from industry introducing the students to the functions of a professional engineer. One clear message from most of those was that even if you plan to enter into company management it is very important to have a technological foundation. A few of the lecturers were CEOs of their companies. Two excursions are included, one to a museum for the former shipbuilder B&W, which currently has a major business as engine designer for ships, and the other to Danfoss, a global Danish company with much emphasis on production technology.

The remaining part, training Interpersonal skills, contains several minor exercises:

1. On day one, the students were put into groups randomly and asked to look for a handicap one could suffer from; describe a device for aid and come up with a better solution for helping persons with that kind of handicap. A report should be handed in within 2 weeks.

2. The above reports are nice examples to have when lecturing on problem solving and report writing. The students though are frustrated about not having had those lectures before they were asked to write the report.

3. When having external lecturers, a group of students should investigate the company the lecturer is coming from, make a 5 minutes presentation of the company immediately before the lecturer starts, and finally prepare a minute from the presentation.

4. In connection with the exercise on making their own study plans, the students are asked to write an essay about why they want to study engineering, what they expect to get out of it, what they want their first job to be (study some adds), and how they think they could qualify for the job (their study plan).

At DTU we have in particular noticed, that most of our incoming students have some training in most of the CDIO 'soft' skills (professional, personal and interpersonal skills). For us the task has more been to make those qualifications visible and maintain their training rather than teaching the students. When entering DTU, all our students have already written some reports, some/most of them have already made presentations using PowerPoint, and they have been doing group-works for more than 5 years.

The assessment is based on the students completing different parts with different weights with different scores. The total score can be found by summing up the products of scores and weights. In our initial version, the evaluation was either pass or fail, and to a large extent this was determined by whether the hand made drawings and the CAD-models and drawings were acceptable or not. It is though important for us to make it clear for the students, that those who work hard will get a better grade, so next time the students will obtain grades. The CAD part was to a large extent evaluated as a portfolio exam where the drawings from different exercises were collected through the semester and evaluated/accepted continuously through the semester. The handicap exercise and reporting the external lecturers both ended with a report, and the lawn mover exercise ended with 3 reports out of which one was presented orally to the class. This leaves us with plenty of material for evaluating each student individually.

The course obtains a very positive evaluation from the students at the end of the semester. It is remarkable that especially the female students say that the course makes them confident that they can understand and describe the working principle of machines they will meet in the future.

This first year course was introduced seven years ago and has been modified lately with inspiration from the CDIO concept. It is noteworthy that the drop out rate after the first year of study in the P&E BSc (formerly Mechanical Engineering) is the lowest at DTU, approximately 15%. Most courses in the first year curriculum are the same for the different BSc. Educations. We therefore believe that it is the CDIO-inspired course that motivates the student to stay at DTU. This type of course is more expensive (teaching hours, workshop, tools, and materials) than traditional courses but we believe that a low drop out rate justifies the cost.

The time slots given to the course were all Wednesday and Friday afternoon (1 PM to 5 PM). In particular the Friday afternoon was used for their workshop exercises and the students had to walk between the workshop, the classroom and the computer lab. On their way between the premises, they passed a student bar opening on Fridays at 2 PM. To our surprise all of the students resisted the temptations from the bar almost to the very last Friday of the semester!

FIRST YEAR COURSES – A COMPARISON.

There is no doubt, that the way the students experience their first year (or even their first semester) is crucial for their continued interest in staying within engineering education. Therefore it is very important that: 1. The first year is well planned, 2. The lecturers responsible for teaching first year courses must be selected carefully, and 3. The students have no prior knowledge of what studying is – let them know before they get bad habits!

In [1] there is a comparative description of the first year courses at KTH, LiU, Chalmers, and MIT involved in the CDIO program. From the above Engineering Work course description one can imagine that there are many similarities and also a few differences between our course and the similar courses given by the other universities. It might be fair at this point to mention, that cultural (social) differences between students have some impact on what can be done and how it could best be done. One example is that Danish students on entry have an almost lifelong experience with group work/team work, writing reports, oral presentations, and some of the other CDIO soft skills. It is important to continue their training from where they are. Also, trying to set up a very controlled environment (everything - what to do and how to do it - is planned and determined on before hand) for our students will make the bright ones leave immediately. A similar behavior may not be found in other countries.

There are several important aspects of a first year course: 1. It must be in a line of progression in technical knowledge, 2. It must actively engage the students in socializing with the other students, 3. It must introduce the students to aspects of what lies within different parts of their future study, and 4. It must be fun and challenging. These goals can be achieved in many different ways and our Engineering Work is just such an example. In our view, when designing such a course, it is very important to compare the objectives that we as lecturers want the students to achieve with the view of the students on the different activities involved in the course. If there is a disagreement the students will typically follow their own path and they will not achieve what the lecturer has intended. The following story illustrates that aspect: The initial 2-week handicap exercise was primarily intended as an appetizer for a lecture on how to write a report. Some of the students were rather mad after the lecture because they wanted the lecture before they had to write the report! The idea that they got more out of the lecture after already having had the practical experience never occurred to them.

Some key issues discussed in [1] are similar to what we have seen:

- A pass/no pass evaluation reduces the student interest in sweating too much; individual grades are cumbersome for the lecturers to produce for large classes but it is necessary.

- Practical project work stimulates curiosity and puts theoretical elements into perspective.

- Female students have a lot of limits moved but it gives them some confidence; they may end up being excellent engineers. In general our female students are much more focused on problem solving and harder working than the typical male student.

- Groups must not be too small, and it is OK to make students change groups for different tasks. It is OK to let one group participate in the evaluation of another group.

- Close contact between students and faculty makes the students feel welcome and important.

In our view, it is important that the first year courses are specially tailored to the background of the entering students professionally, socially and culturally. It is also important to put into those course some challenges and fun parts that trigger in particular the bright students because they have the resources to influence the whole class in a positive (or in a negative) direction. It works in a similar way with some of the female students – some can make the boys work hard! They learn what they do and the more they do the more they learn.

CONCLUSIONS

It is important that both curriculum and teaching in an engineering education are both planned with proper respect to the qualifications of the students entering, the social and cultural traditions of the school and the requirements to the final product – the engineers. This is though not to be used as an excuse for not trying to improve the educations by taking up ideas and experiences obtained elsewhere.

The change of the curriculum caused by the Bologna declaration also enforces us to be much more specific in our description of competences; both on the entry level and on the exit level of our educations. This is not a bad thing. In case such clear and stringent descriptions of entry competences do not exist, there will be a problem if and when the students start to utilize the freedom aimed at in the declaration for taking parts of their education at different European universities. In the process of writing up these competences we are confident that being involved with the CDIO way of thinking education can be of major help primarily because CDIO is so well documented.

Though it is important in the first year to build a solid foundation in mathematical and physical knowledge, it is also important to have a course, that gives the students a realistic impression of what is Engineering Work – what will they be doing for the rest of their career. In such a course it is possible and important also to introduce some basic engineering skills (both technical skills and personal and professional skills). In case this involves some kind of additional 'nursing', we find that such resources are well spent. One important goal is also to clarify for the student whether this study leads to their dream work or not. In the latter case, it is important they do drop out early.

ACKNOWLEDGEMENTS

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APPENDICES

Four different plans of study are adjourned. Though very different, they are all generated from the same basic curriculum description (Bachelor of Science in Production and Engineering Design).

Study plan #1: Production and Engineering Design Bachelor specialized in *Engineering Design and Mechanics*

A study plan full filling the requirements for Basic Science courses with electives (45 credits), Technological courses (45 credist), projects and general courses (45 credits), and a list of proposed elective courses (45 credits).

	MONDAY		TUESDAY		WEDNESDAY		THUSDAY		FRIDAY		
Sem-ester	1 A	2 A	3 A	4 A	5 A	5 B	2 B	1 B	4 B	3 B	3-WEEKS
1	10022 Physics 1		01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1	11000 (10 p) Engineering	11000 (10 p) Engineering			01005 Advanced Engineering Mathematics 1	11000 (10 p) Engineering	42302 Production Technology (workshop training)
2	10022 Physics 1	41501 Strength of Materials	01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1		42301 Production Technology (Fundamentals)		42110 Materials Science	01005 Advanced Engineering Mathematics 1		
3		26027 Fundamental Chemistry		10042/44 Physics 2			41502 Strength of Materials 2	02xxx Programming		42610 Theory of Science in Engineering	41811
4	PROJECT (10 p)		41401 02402	42201 41560	41603 (5p) Engineering Design	41603 (5p) Engineering Design	01035 Advanced Engineering Mathematics 2		41202 Principles of Naval Architecture and Offshore Engineering 1		PROJECT (10 p)
5		41670	41312 Fluid mechanics	42405 41612	01246	01246	41670 41313	41511 41210	42405 41612		41822 41272
6	BACHELOR PROJECT (15 p)	BACHELOR PROJECT (15 p)	41611		41271	41271		BACHELOR PROJECT (15 p)	41614	41611	

Recommended elective courses within Engineering Design and Mechanics (at most 45p)

01246	Partial Differential Equations – Applied Mathematics	10 p	41560	Mechanical Vibrations	5 p
02402	Introduction to Statistics	5 p	41611	Machine Elements	10 p
41210	Load and Global Response of Ships	7,5 p	41612	Product Design and Documentation	10 p
41271	Ship Design	10 p	41614	Dynamics of Machinery	5 p
41272	Economic and Environmental Perf. of Transp. Syst.	5 p	41670	Motion Control	10 p
41313	Wind Turbine Technology and Aerodynamics	7,5 p	41811	Experimental Mechanics	5 p
41511	Strength of Materials 3 (Fiber Laminates)	5 p	41822	Experimental Methods in Fluid Mechanics	5 p

Study plan #2: Production and Engineering Design Bachelor specialized in *Energy Engineering*.

A study plan full filling the requirements for Basic Science courses with electives (45 credits), Technological courses (45 credist), projects and general courses (45 credits), and a list of proposed elective courses (45 credits).

	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		
Sem-ester	1 A	2 A	3 A	4 A	5 A	5 B	2 B	1 B	4 B	3 B	3-weeks
F1	10022 Physics 1		01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1	11000 (10 p) Engineering	11000 (10 p) Engineering			01005 Advanced Engineering Mathematics 1	11000 (10 p) Engineering	42302 Production Tech-nology (Work-shop Training)
S2	10022 Physics 1	41501 Strength of Materials 1	01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1		42301 Production Technology (Fundamentals)		42110 Materials Science	01005 Advanced Engineering Mathematics 1		
F3		26027 Fundamental Chemistry	41312 Fluid Mechanics				41502 Strength of Materials 2	02xxx Programming	02405 Probability Theory		41822
S4	FAG-PROJECT (15 p)		41401 Fundamental Engineering Thermodynam ics		41603 (5p) Engineering Design	41603 (5p) Engineering Design	01035 Advanced Engineering Mathematics 2	02601	41202 Principles of Naval Architecture and Offshore Engineering 1		FAGPROJECT 10 p
F5		41414	02402	41814	41402 (5p)	41402 (5p)	41414			42610 Theory of Science in Engineering	41410 41418
S6	BACHEL OR PROJECT	BACHELOR PROJECT (15 p)	41813	41415			41815	BACHELOR PROJECT (15 p)	41415	41813	

Recommended elective courses within Energy (at most 45p)

02402	Introduction to Statistics	5 p	41418	Energy Production and Air Pollution	5 p
02601	Numerical Algorithms	5 p	41813	Design of Energy Systems	10 p
41402	Simulation of Energy Systems	5 p	41814	Heat Transfer	5 p
41410	Basic course in Fuel Cells	5 p	41815	Heating, Cooling and Air Conditioning	5 p
41414	Internal Combustion Engines and Transport	10 p	41822	Experimental Methods in Fluid Mechanics	5 p
41415	Power Plants	10 p			

Study plan #3: Production and Engineering Design Bachelor specialized in *Industrial Production*.

A study plan full filling the requirements for Basic Science courses with electives (45 credits), Technological courses (45 credits), projects and general courses (45 credits), and a list of proposed elective courses (45 credits).

	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		
Sem-ester	1 A	2 A	3 A	4 A	5 A	5 B	2 B	1 B	4 B	3 B	3-WEEKS
E1	10022 Physics 1		01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1	11000 (10 p) Engineering	11000 (10 p) Engineering			01005 Advanced Engineering Mathematics 1	11000 (10 p) Engineering	42302 Production Technology (Workshop Training)
F2	10022 Physics 1	41501 Strength of Materials 1	01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1		42301 Production Technology (Fundamentals)		42110 Materials Science	01005 Advanced Engineering Mathematics 1		42120
E3		26027 Fundamental Chemistry		10042/44 Physics 2			41502 Strength of Materials 2	02xxx Programming		42610 Theory of Science in Engineering	42120 42341
F4	PROJECT (10 p)		41401 Fundamental Engineering Thermodynamics	42201 Process Technology	41603 (5p) Engineering Design	41603 (5p) Engineering Design	01035 Advanced Engineering Mathematics 2			PROJECT (10 p)	42120 42226 42260
E5	42213	42230 42415	42221	42405 Introduction to Production and Operations Management			42230	42213	42405 Introduction to Production and Operations Management		42120 42250 42341
F6		42130	42415		BACHELOR PROJECT (15 p)	BACHELOR PROJECT (15 p)	42130			BACHELOR PROJECT (15 p)	42120 42260

Recommended elective courses (at most 45p)

42120 Laboratory Course in Metallurgy	5p	42230 Polymer Processes	10p
42130 Metallic Materials	10p	42250 Laboratory Course in Process Simulation	5p
42213 Industrial Forming and Cutting of Metals	10p	42341 Development/optimization of production systems	5p
42221 Metallurgy, Design and Manufacturing of Cast Components	5p	42415 Engineering Economy	5p
42226 Experimental welding technology	5p		

Study plan #4: Production and Engineering Design Bachelor specialized in *Planning and Operations Management.*

A study plan full filling the requirements for Basic Science Courses with electives (45 credits), Technological courses (45 credits), projects and general courses (45 credits), and a list of proposed elective courses (45 credits).

	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		
Sem-ester	1 A	2 A	3 A	4 A	5 A	5 B	2 B	1 B	4 B	3 B	3-WEEKS
E1	10022 Physics 1		01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1	11000 (10 p) Engineering	11000 Engineering			01005 Advanced Engineering Mathematics 1	11000 Engineering	42302 (5 p) Production Technology (Workshop Training)
F2	10022 Physics 1	41501 (5 p) Strength of Materials 1	01005 Advanced Engineering Mathematics 1	01005 Advanced Engineering Mathematics 1		42301 (5 p) Production Technology (Fundamentals)		42110 (5p) Materials Science	01005 Advanced Engineering Mathematics 1		
E3		26027 (5 p) Fundamental Chemistry	42410	10042/44 Physics 2		42435	01035 Advanced Engineering Mathematics 2	02xxx Programming	42610 Theory of Science in Engineering		42341
F4	PROJECT (10 p)		42410 42415	42201 Process Technology	41603 (5p) Engineering Design	41603 Engineering Design		42412			PROJECT (10 p)
E5		42415 42421 42440	41312 Fluid Mechanics	42405 Introduction to Production and Operations Management		42435		42412	42405 Introduction to Production and Operations Management		42341
F6	BACHELOR PROJECT (15 p)	BACHELOR PROJECT (15 p)	42410 42415			BACHELOR PROJECT (15 p)		42412			

Recommended elective courses (up to 45p)

42341 Development/optimization of production systems	5p	42430 Project Management	5p
42410 Basic Accounting and Budgeting	7,5p	42435 Entrepreneurship and Company Start-up	5p
42412 Introduction to Economics	5p	42440 Technology and Economics	5 p
42415 Engineering Economy	5p	42470 Introduction to Industrial Environmental Management	5 p
42421 Management and Organization	5p	42521 Introduction to Working Environment	5p
42425 Business Law for Engineers (evening course)	10 p		