# THE EDUCATIONAL SYSTEM IN CIVIL ENGINEERING AT AALBORG UNIVERSITY, DENMARK

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## 1. Introduction

The aim of this paper is to give an overview of the educational system at Aalborg University (AAU), with special focus on the civil engineering programme given at AAU today.

This introduction contains a brief historical overview of AAU's educational theory and practice along with a brief information of the Danish educational system. The Danish educational institutions where teaching and research within technical subjects are performed are then mentioned. This leads up to a brief description of today's AAU.

Chapter 2 contains a general description of AAU's problem-oriented and project-organized form of study, which is the overall educational principle in all AAU educations. In chapter 3 a detailed description of the civil engineering programme is given, and the overall objective, themes, specialist subjects and courses of the indidividual semesters are explained. Finally, a short description of final-year projects is given.

The educations have been evaluated by the university staff and students as well as by the users of the candidates, i.e. industrial companies, public institutions and research institutions. This evaluation is given in chapter 4. Finally, a conclusion is given in chapter 5.

### 1.1 Educational theory and practice

Most people probably connect university teaching with *lectures*. This form of educational theory and practice has indeed been used for many years and still is. However, through the ages this form of teaching has been subject to substantial criticism. The great Danish author Ludvig Holberg (1684 – 1754), who gave lectures at the University of Copenhagen, was of the opinion that the students did not always benefit from the lecture form. For example, Holberg said that it would be wholesome for the students if the teachers were transformed into "respondents", so that they were present at certain places and times to answer questions from the students. The teachers could then tell the students what they wanted to know and explain matters they could not understand in the books and writings they had studied. The students would then be taught precisely what they wanted to know, and could be helped to solve problems they could not solve themselves.

Formerly, there were other forms of teaching besides the lecture form, namely the *disputes*, where the subject was dealt with in some kind of discussion between two or more participants. However, it was far from the form of discussion known today. Arguments and counterarguments were presented, but there were detailed rules for procedure and contents.

The disputes were arranged by a teacher, who formulated and advertised the problems to be addressed in advance.

The development of the art of printing made a faster and broader communication of knowledge and exchange of ideas possible, and thus the universities were gradually changed. However, knowledge was still given through lectures that were repeated year by year. Science did not develop very fast and the teachers' sources of information were very limited.

About 1800 a new scientific openness gradually arose along with the modernization of the universities in Europe, for example in France as a result of the revolution. The connection between teaching and research gradually became a fundamental principle of the universities and different forms of teaching were introduced. The *lecture,* for example, became a very significant part of the teaching as well as the *exercise*, where each participant is given a problem to solve individually and to present orally or in writing to the exercise group. Other concepts to be mentioned are the *seminar,* which is the more scholarly teaching, and finally the *colloquy* comprising a limited number of students. This can be seen as a more research oriented form of exercise. There are no problems to be solved individually by students, but there is a predefined subject to be discussed by all the participants.

We then make a great leap forward to our time. In Denmark a debate was started at the end of the sixties and in the seventies, which was dominated by the efforts to make the educations more efficient by better planning and technical aids and by involving the students in the planning and contents of the educations. This resulted in the establishment of so-called "university centres" in Denmark at the beginning of the seventies, namely in Roskilde in 1972 and in Aalborg in 1974. The background was a general pressure for structural reorganization of the university educations to keep the consumption of economic resources under control. Furthermore the educations became more sensitive to the trends of the labour market. The educational model became a system, where bachelor levels and the master levels were combined in a system with broad access in the form of basic study programmes (described later) and with many specialized steps and levels of final examination. At the same time a new concept of rather extensive principles of educational theory and practice was introduced, namely: project work in groups, problem-oriented and interdisciplinary teaching. Lectures and exercises still played an important role, but the project work was given very high priority in the form of study and teaching. This is described in more detail in chapter 2. The role as project supervisor held many new aspects that were rather new to the educational theory and practice of the university.

## 1.2 The Danish educational system

In Table 1 it is assumed that the student proceeds directly from one educational institution to the other. However, in recent years it has become the general situation that the student spends a year or two doing other things, for example travelling abroad or working, before starting at the university. Often it is necessary to seek more information of the different educations and study programmes as it can be very difficult to decide today which one to choose. The student may also discontinue the studies after the master degree and wait for a couple of years before deciding on a Ph.D. education. The length of education specified in Table 1 is based on the prescribed study periods with no extension whatsoever.

*Table 1. Overview of the Danish educational system.*

| Age (years) | Length of education (years) | Type of education |
|---|---|---|
| 6 | 1 | Preschool class |
| 7 | 9-10 | Compulsory education<br>Primary and lower secondary school<br>Public or private schools |
| 17 | 3 | Gymnasium (Upper secondary school) |
| 20 | 3(3½) | University, Bachelor degree |
| 23 | 2 | University, Master degree |
| 26 | 3 | University, Ph.D. degree |

## 1.3 Institutions in Denmark with higher education within the technical area

There are about 5.2 mio. inhabitants in Denmark. Therefore, there are only a limited number of institutions offering higher education within specialist technical subjects. The oldest of these institutions is the Technical University of Denmark (DTU) located in Copenhagen and founded in 1829. DTU offers bachelor, master and Ph.D. degrees within a wide range of specialist areas. The same applies to AAU founded in 1974 and, therefore, a very new and modern university with a special form of study and teaching, which is described in detail in this paper. Furthermore, the University of Southern Denmark offers the same levels as DTU and AAU, but only within relatively limited specialist areas.

In addition to these three universities the Engineering Colleges offer teaching at the bachelor level. Engineering Colleges are located in a number of large Danish cities.

In the following we shall focus on the form of study used at AAU, which differs at significant points from that used at other technical universities and colleges.

## 1.4 Some facts about Aalborg University

AAU was inaugurated in 1974 and has more than 13,000 students. AAU has three faculties:

The Faculty of Humanities
The Faculty of Social Sciences
The Faculty of Engineering and Science

AAU is divided into 21 departments. One of these is located in Esbjerg, which is 200 km from Aalborg. The members of the scientific staff and the technical and administrative staff are employed at departments. The students are organised in staff- student committees, and there are the following staff- student committees at the Faculty of Engineering and Science:

A: Architecture and Design
B: Civil Engineering
E: Electronic and Information Technology

F: Science
G: Basic Studies
H: Entrance Course
K: Chemistry, Environmental Technology and Biotechnology
L: Surveying and Planning
M: Industry and Export
T: Management of Technology

## 2. The educational system at Aalborg University

*Tell me and I will forget*
*Show me and I will remember*
*Involve me and I will understand*
*Step back and I will act*

Chinese proverb

Two words characterize the education at AAU:
*Problem-oriented* and *Project-organized* (group-organized)

The duration of a project is one semester corresponding to five months. These five months (September to February or February to July) are divided into three periods of five weeks each plus an additional five week period for examination and evaluation. The students are working in groups and every group has a project (problem) to solve within each semester. In the next semester new groups are formed and new projects (problems) will be solved.

In each semester half of the time is used for the project and the other half for course activity. At the beginning of the semester the course activity is high (the project activity low) and reverse at the end of the semester.

From the first day at AAU the students work in accordance with these principles. During the first year – the so-called *Basic Year* – the students work with very broad problems. First of all the students have to learn to work in groups and make a project and secondly, they have to learn some fundamental knowledge such as mathematics, physics and IT technology. They also learn how to evaluate technical solutions in a social connection. The project work during the next two years can be characterized as *design oriented* or *"know how"* knowledge. After these first three years the student can obtain a bachelor degree by working one semester more on a final-year project. If the student wants a master degree he/she must study for two more years to be more specialized. These two years can be characterized as very *problem- oriented* and can also be called the *"know why"* period.

The project-organized form demands a high degree of *supervision*. Every group has a main supervisor and one or more co-supervisors. This is necessary because many projects involve different topics which can require the help of many teachers / supervisors. The idea is that the students must not feel that the curriculum is only composed of many disciplines, but they must learn to understand that there is a close connection between the disciplines. The projects, therefore, involve many disciplines and combining these is very important. Therefore, the

starting point for many projects is very often practical problems and often the projects are solved in co-operation with public authorities, consulting companies and the industry.

Another very important necessity is a *group room* for each group. The size of groups can vary from 6 - 8 students at the Basic Year and the first semesters to 1, 2 or 3 students at the final years. This means that the university has to be equipped with many rooms that are relatively small in size. Every group room must be equipped with a table and a chair for each student and computer connections. A group room is shown in Figure 1.

Each semester the group will solve a problem and prepare a report. The problem must be analysed before it can be solved and the group will have to seek help from many different sources before the report can be written. This is illustrated in Figure 2.

*Figure 1 Typical group room at AAU*

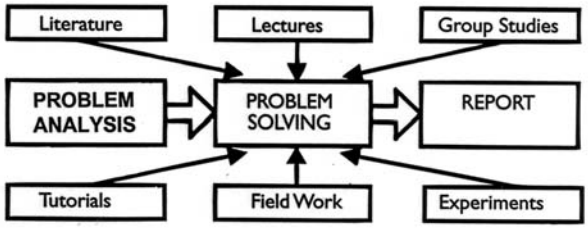


*Figure 2 Many sources are needed to solve the problem*

As mentioned above half of the time is used for the project and the other half is used for the courses. Two types of courses are introduced. The first type is related to the curriculum and is called *study programme courses* amounting to about 25% of the courses. These courses can be courses in mathematics, physics and fundamental (basic) knowledge within the curriculum. These study programme courses have individual examinations of the students and are often in the form of written examinations, but oral examinations are also applied.

The other type of courses is the so-called *project theme courses* amounting to about 75% of the courses. The project theme courses are evaluated through the project evaluation (see later).

A course can typically correspond to 1, 2 or 3 ECTS points. One ECTS point corresponds to 5 times 4 hours of learning. This also means that the minimum course activity is equal to four hours (half a day). A typical distribution of such a half day with course activity can be:

1. 1st lesson given by the teacher
2. A short break
3. 2nd lesson given by the teacher
4. A short break
5. Exercises in the group rooms. The teacher and often some additional teachers visit the group in their own group room one, two or three times to help the students to solve the

exercises given in connection with the theory given by the teacher during the two lessons.

The lectures are given for all the groups at the semester in a lecture room but it is important to notice that the last two hours are spent in the group room where the group is alone with the teachers and can discuss the problems.

At the end of the semester the group shall write a report (100 – 200 pages) and copies are given to the supervisors and an external examiner. All members of the group are responsible for the report and in practice the students at AAU use very much time to write this report. When the supervisors and the external examiner have read the report an oral examination takes place. An oral examination of a 6 – 8 member group may last almost a whole day. A typical oral examination of one group has the following agenda:

1. All members of the group takes part in the presentation of the report (1 hour)
2. General comments from the supervisors and the external examiner on the presentation and on the report (1 hour)
3. Examination in the topics in the different parts of the project. This is an individual examination of all members in the group. The report forms the basis of this examination but since the project theme courses are also evaluated general questions in relation to these courses are also asked.

Of course some breaks are necessary. But it is a very tough and long day for the students and the supervisors since many technical fields are involved, see for example chapter 3 where the courses and the themes of the different semesters are given.

After each semester the students shall write a report about the semester and this report is sent to the staff-student committee. The staff-student committee consisting of five teachers and five students is responsible for the syllabus and the curriculum. The chairman of the staff-student committee is a teacher.

More information about the educational system at AAU can be found in (Kjersdam & Enemark, 1994) where many references are given. More information about civil and structural engineering education can be found in (Civil and Structural, 2000).

## 3. The civil engineering programme

As mentioned in chapter 2 the basic year education which is explained in chapter 3.1, is compulsory for all new students under the Faculty of Engineering and Science at AAU. In chapter 3.2 a general description of the civil engineering programme is given. As examples the 3$^{rd}$ and 7$^{th}$ semesters for structural engineering are explained in detail in chapter 3.3 and 3.4. In chapter 3.5 final-year projects are mentioned.

### 3.1 The basic year

From the very first day at Aalborg University the students are working in groups with problem-oriented and project-organized education. In the basic year (1$^{st}$ and 2$^{nd}$ semester) the

students are working with three projects called P0 and P1 in the 1st semester and P2 in the 2nd semester. The workload for these projects corresponds to 4 ECTS (P0), 21 ECTS (P1) and 22 ECTS (P2). As the total workload for one semester corresponds to 30 ECTS the rest of the workload comes from the so-called general courses or programme courses. These are Mathematics (1A) in the 1st semester (5 ECTS) and Mathematics (2A), Mechanics and Static in the 2nd semester (8 ECTS).

When the P0 project is finished there is an individual evaluation of the project for all the students in the group. Only the evaluation "passed" or "failed" is given. For the other two projects in the basic year there is also an individual evaluation for all the students, where marks from 0 to 13 corresponding to the general Danish marking system are given. The average mark is 8 and to pass the examination a minimum of 6 is required.

The P0 project is a very short introductionary one. An example of an overall theme for the P0 projects could be: "The different roads in Denmark" related to subjects as traffic planning, construction, foundation and environmental aspects.

The P1 project is a larger project. Examples of such a project could be: "Ventilations in buildings", "Aalborg Airport", "Offshore wind turbines", "Pure water in Aalborg" and "Paths for bicycles in Aalborg". In connection with the projects some project-oriented courses are given as for example: "Information Technology", "Technology – Human beings and the society", "How to write a project" and other courses related to the projects. The workload in connection with these project-oriented courses is 10 ECTS.

The P2 project in the 2nd semester is built up in the same way as P1 but it includes more technical topics. Examples of such projects could be: "A new Aalborg Tower", "A bridge made of laminated wood", "Town planning in Aalborg" and "Using energy from waves". In connection with these projects some project-oriented courses are given, for example: "Loads and safety", "Models in civil engineering", "Environmental aspects" and other courses for the different projects.

## 3.2 The general structure from the 3rd to the 10th semester

The civil engineering programme at Aalborg University contains educational programmes for both bachelor and master levels. Each year approximately 100 students start on the programme and with a dropout rate of only 10%, 90 of these students finalize an education within this programme. The economic consequence of this low dropout rate is a possibility to finance 5 different educations. These are:

- Structural Engineering
- Management in the Building Industry
- Indoor Environmental Engineering
- Transportation Engineering
- Water and Environment

These educations are all tailored to the needs in the relevant branches of the Danish industry. This industry is working all over the world, which makes large demands on the educational programme and on the students. One of the vision elements is to offer an attractive

programme for the best part of the students from the upper secondary school. This vision has for a long period been fulfilled. The consequence is that both the candidates and the industry are very pleased with the study programme.

The structure of these educations is shown in Figure 3:

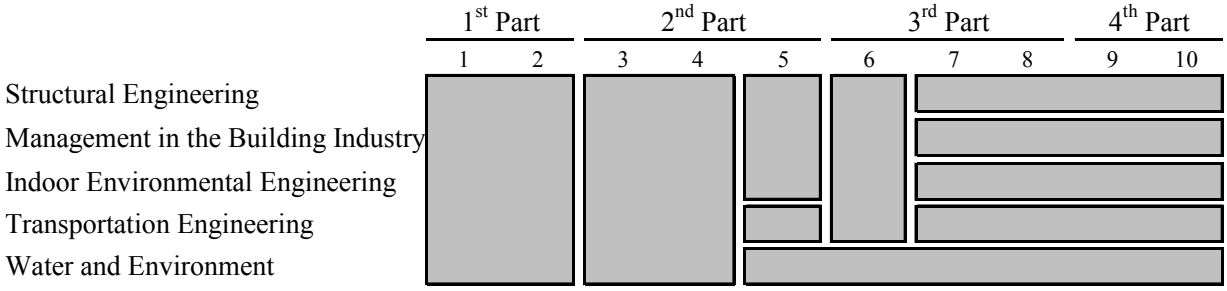


*Figure 3. The general structure of the Civil Engineering Programme*

A civil engineer needs to be interdisciplinary and fortunately this is also a wish from the students. As the students work with the same problems and have the same courses in the first two parts of the study it is relatively easy to make an economic educational programme. As shown in Figure 3, all the students in the first 4 semesters work together, i.e. "structural students" may e.g. be working together with "environmental students". After these 4 semesters the final specialization starts. In the final part of their study the students are only working together with students from their own specialization. It is obvious that the last part of the study programme is more expensive to run than the first.

In Figure 4 and Figure 5 the courses for the 2nd part of the study and the figures for the 3rd part for the specializations in Structural Engineering and Indoor Environmental Engineering are shown.

As it appears from Figure 4, courses such as static, structural engineering and hydraulic are central elements in the programme. Together with other courses the basis is made for the students project work. Courses above the double line is study programme courses where the student has to pass a test after the course. Courses between the two double lines are project courses, which are evaluated through the project evaluation. The texts below the bottom double line are titles of the projects and have different sizes. On the 3rd semester the project has a duration corresponding to 14 ECTS, where it for the 5th semester in the Water and Environment programme has a size of 20 ECTS.

As supplement to these courses free study courses are offered to the students. These free study courses are beyond the normal semester of 30 ECTS.

Two examples of the semesters will be given in the following. One is a presentation of the 3rd semester and one is a presentation of the 7th semester in the Structural Engineering programme.

## 3.3 The 3rd semester

The 3rd semester is common progress for all students. During this semester the students are working with planning, structures, hydraulics, environment and materials science.

As already explained, each semester has a theme and all the project groups are working under this theme. However the projects are not identical since the groups have the possibility to choose different geographical locations of their projects and weight the subjects in different ways.

The theme of the 3rd semester is "Infrastructure" and in the following this semester is described in more detail as an example of the educational system at AAU.

The starting point of the project is a problem with traffic in a small town or a village. This problem can be a distance of a road with some noise problems, traffic jam or many road accidents. The project group has to work with different solutions to solve the problems as for example speed limits regulations or construction of a new by-pass road around the town (village). The project group will discuss the advantages and disadvantages of the different solutions and choose the best solution. This opens the way for working with different subjects. First the group has to determine the location of the new road, the necessary traffic capacity, the soil conditions, the load-bearing capacity of the new road and the crossroads. The new road will probably cross for example a small river or a railway and there is thus a need for a bridge. The group will sketch different solutions for such a small bridge which involves knowledge of static, loads, stress analysis, deflections and material science. However, other aspects can also be included in the project. For example, more environmental

| ECTS | 3rd Semester | 4th Semester | 5th Semester | | |
|---|---|---|---|---|---|
| 1 | Statistics | Hydrothermal | Differential Equations | | |
| 2 | | Building Physics | and Numerical Methods | | |
| 3 | Concrete Technology | Fundamental Static's | Rural Environmental Planning | | Material Physics |
| 4 | | and Strength Theory | | | |
| 5 | Surveying | Concrete Structures | Geographical Information System | | Torsion and |
| 6 | Geology | | | | Stability Theory |
| 7 | Fundamental Static's | Timber Structures | Water Catchement, | Traffic Planning | Continuum Mechanics |
| 8 | and Strength Theory | Soil Mechanics and | Supply and Treatment | | |
| 9 | Fundamental Fluid | Foundation | | Traffic Models | Steel Structures |
| 10 | Dynamics and | | | Traffic Safety | Strength of Soil |
| 11 | Stream Hydraulics | Sewerage | | | Foundations |
| 12 | Structural Design | | | Planning in | Building Services |
| 13 | | | Water Supply | Rural Districts | and Heating |
| 14 | Road and | Town Planning | | | Ventilating Technique |
| 15 | Traffic Technique | | | | |
| 16 | | | | The Traffic and its | The Building and |
| | Infrastructure | The Building and | | consequences | Building Services |
| 30 | | its Environments | | | |

*Figure 4. The courses in the 2nd part of the programme*

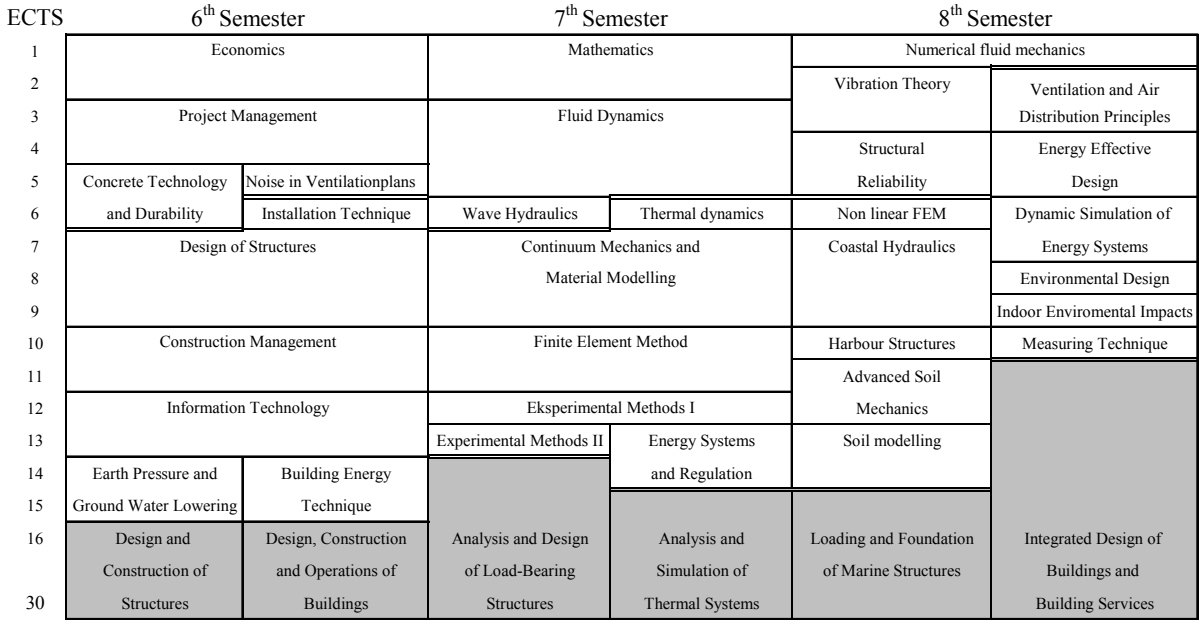


*Figure 5. The courses in the 3rd part of the programme*

aspects may be analysed and different solutions may be considered to solve such problems. Furthermore hydraulic problems can arise and must to be analysed.

The project is "a real problem" and is often solved together with public authorities and consulting companies. Such a co-operation between the university and the surrounding society is very important.

It is required that every group works with all the different fields but they may choose to work more on a specific aspect of special interest for the group.

As described in chapter 2 the students must have some knowledge on the different subjects involved in the project before they can come up with a good solution of the problem. This knowledge is given through the project-related courses. This interaction between the project and the project-related courses is a very important and central part of the educational model at AAU. Also some so-called "free activities of study" are offered.

As explained in chapter 2 the project-related courses are evaluated in connection with the examination of the group. The general courses are evaluated as a written or oral individual examination of all the students.

## 3.4 The 7th semester for structural engineering

The theme for the 7th semester is "Analysis and Design of Load – Bearing Structures" and the basic purpose of this semester is to give the students the necessary knowledge to analyse advanced structures with respect to strength and stiffness. Only static forces are considered. This analysis is based on analytical and numerical methods. Furthermore, the students have to do some experimental work and evaluate the results from the measurements concerning for

example assumption of the model and uncertainty. Different types of transducers are used but in most of the projects forces, displacements and strains are measured. The results from the different methods have to be compared and some conclusions must be drawn.

Normally the students work with a structure for which the stresses and deformations can not be determined by "simple calculations by hand" with sufficient accuracy. However some simple models are used in the beginning of the project to give some approximate solutions of the problem. Numerical models for the structure are formulated and very often the Finite Element Method is used. The results are evaluated as regards for example accuracy, number of elements, type of elements and computer time.

As examples of projects on the 7th semester the following can be mentioned:

1. Plane stress analysis of a dics (slab) with a circular hole
2. Beams with varying cross sections
3. I-beams of steel with different holes in the web
4. Curved beams

The total workload for the semester is 30 ECTS just as for the other semesters.

### 3.5 Final-year projects

The final-year project is a very important part of a students curriculum. For students obtaining a bachelor's degree the final-year project is prepared in the 7th semester. No courses are offered and all the time is spent on the project. For students obtaining a master's degree the final-year project can begin in the 9th semester and finish in the 10th semester and thus have duration of one year. In the 9th semester some courses are offered while no courses are given at the 10th semester. The final-year project for students obtaining a master's degree may also have duration of 5 months in the 10th semester.

Very often two students form a group for their final-year project, but groups with one or three students are also possible.

The final-year projects are very often written in co-operation with public authorities, consulting companies and the industry.

## 4. Evaluation of the "Aalborg Model"

The students with bachelor's and master's degrees from Aalborg University are expected to be qualified to undertake large and complicated tasks, to combine insight from different fields, to analyse new problems and to learn themselves new fields.

But of course there may also be some scepticism. Will the graduates be able to meet the demands of the engineering profession? Will the graduates reach the academic standard? And many other questions can be asked.

During the nineties several groups evaluated the educational system at Aalborg University. Their conclusions are described in detail in (Kjersdam & Enemark, 1994) and in general all the evaluations were positive.

A new evaluation of the Faculty of Engineering and Science at Aalborg University were performed by an expert panel setup by the Danish Ministry of Education (EVA, 2002 – in Danish). They commented favourably on the education and especially the results within the problem-oriented project work with high completion rates. The education was of high quality with great relevance for the trades and industries. The unemployment rate for the graduates was lower than 1%.

## 5. Conclusions

The educational system at Aalborg University is characterized by two words: *problem-oriented* and *project-organized*. This educational system has been applied at the university since the beginning in 1974 and only minor changes have been made during the years.
The supervisors play an important part in the educational system as the project work is carried out by the project groups. This promotes a strong motivation for research by the supervisors. Many of the student projects may be based on the current research activities of the supervisors.

This interaction between education and research allows for the development of the necessary dynamic effect of innovative education.

## 6. References


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