Finn Kjersdam
Stig Enemark

Aalborg University Press

CONTENTS

1. PREFACE
2. SUMMARY/SAMMENFATNING
3. PROBLEM-ORIENTATION AS A LINK BETWEEN THE ACADEMIC AND THE PROFESSIONAL WORLDS
    1. Profession, Research and Education
    2. Applied Science
    3. Educational Innovation
4. PROJECT-ORGANIZED EDUCATION AND HOW TO IMPLEMENT IT
    1. Organizing the Curriculum into Themes
    2. Running the Themes
    3. The Process of the Project Work
    4. Evaluation and Examination
    5. The Role of the Supervisor
5. EVALUATION OF THE AALBORG EXPERIMENT
    1. Introduction to the Evaluation
    2. The Project Work
    3. The Balance and Coherence in the Programmes
    4. The Supervisor's Qualifications
    5. Examination and Recognition
    6. Achieved Knowledge
    7. Preparation for the Profession
    8. Project-Organized versus Traditional Education
6. BIBLIOGRAPHY
7. AFTERWORD
8. PUBLICATION NOTES

PREFACE

This book has been written to pay homage to our university and our colleagues, who during the past twenty years have developed a unique educational system.

As always when we are dealing with real innovations, there were only fragmentary theories and no experience and training, when we took off. Learning by doing was the code of the process as well as the code of the educational system that we tried to build.

Today we have a university with ten thousand students equally divided between undergraduates and graduates, where all programmes are based on problem-orientation and project-organisation. During those twenty years the programmes have been developed into a spectrum of versions of the problem-oriented project-organized types of education within humanities, social sciences, the sciences and engineering.

This book is focused on our experience within engineering and the natural sciences.

The first chapter about the concept is written in co-operation, the second chapter on how to do it is written by Enemark, while the third chapter on the evaluations is written by Kjersdam.

The book is edited by Kjersdam.

Aalborg 1994

Finn Kjersdam & Stig Enemark

SUMMARY

In a real sense the establishment of Aalborg University in 1974 was an exiting experiment in higher education as important as for instance, the Open University concept in the United Kingdom. Real innovations in education of this importance are rare and Denmark can be justly proud to have taken a leadership role in formulating a novel project-centered higher education method.

International Evaluation Panel.

Twenty years ago Aalborg University's project-organized studies were introduced. The experience since then has proved this to be an important innovation in higher education.

The curriculum in engineering as well as in the natural science is project-organized from the day the freshmen arrive until their graduation.

The first year the freshmen learn to work in project-groups. The next two years in the undergraduate programmes the project work is mainly design-oriented. The last two years in the graduate programmes the project work is mainly problem-oriented.

In the design-oriented project work the students deal with know-how problems which can be solved by theories and knowledge they have acquired in their lectures. In the problem-oriented project work the students deal with unsolved problems within science and profession. The project-work has a know-why approach and is supported by relevant lectures.

The duration of each project is one semester. In the programme half of the time is distributed to project work, 25% to courses related to the project and 25% to courses related to the curriculum.

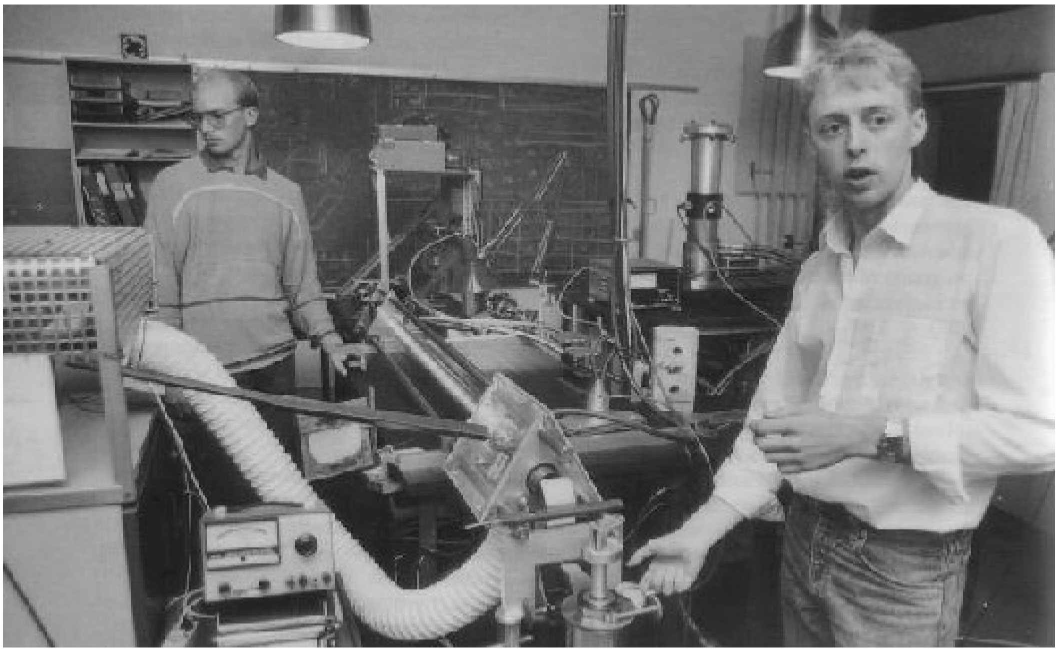
This educational system has proved to have great internal adaptability. It has not been difficult to adjust and change the educational programmes in accordance with developments in technology, society and economy. The system is innovative and has been able to cope with current problems in the professions and in society.

The system has also shown great external adaptability. The graduates are well prepared to solve the unknown problems of the future and to extend their professional work outside their major.

The project-organized education demands a high degree of supervision and office-space for the students. Each project-group requires the use of an office at the university and continual supervision by a member of the faculty. The ever changing perspective, initiated by the internal adaptability, demands lectures to be constantly changing, or renewed. This demands much preparation and affects the resource economy adversely. The internal adaptability and the free choice of the students create a demand for flexibility in the distribution of resources at the University.

But it is also an effective educational system. 80% of the students pass their examination at the prescribed time and the Danish Parliament's state audits

assessed Aalborg University to have the most effective of the nine Danish engineering educational institutions.



The results and experience of the research which is carried out at the university is easily incorporated in the teaching programmes because of their close relationship to problem-solving, and because of their direct integration with the educational system and its programmes.

The graduates achieve great experience in interdisciplinary team work and they will normally possess the latest scientific and methodological knowledge, which is thus spread quickly and free of charge to both public bodies and industry, due to the employment of new graduates.

The engineering education in Aalborg has been evaluated and compared with traditional engineering education. This was done by two international panels, as well as by external examinators, graduate engineers and their employers and undergraduate and graduate students. Evaluation assessed that there were no differences in quality or level between engineers graduated from Aalborg University and the other Danish university engineering education in Copenhagen.

But the evaluation also assessed significant differences between the profiles of the graduates from the two Danish engineering universities.

The engineers from Aalborg were assessed to be stronger in problem-solving, communication, co-operation and general technical knowledge, while the traditional engineers were assessed to be stronger in specific technical knowledge and methodology.

The Aalborg engineering programme was assessed to be complementary to the traditional engineering programmes, serving slightly different needs for students and industry.

Most of the graduate engineers from Aalborg had no difficulties in their first job and felt confident after three months. A small number of the civil engineers had felt difficulties with practical experience in their first job, while a small number of the other engineers had felt some difficulties in the field of organization and industrial culture in their first job. There was convincing agreement between the composition of the knowledge and experience used in the project-oriented education and in the professional engineering practice. The only difference was slightly more emphasis on theoretical engineering and science at the university and on economics in industry. Surprisingly, computing and foreign languages were more important than theoretical science for the graduate engineers in their jobs.

After three years of employment, the main source of the applied professional knowledge still derived from their project work at the university, while only a minor part of the applied knowledge derived from taught courses, colleagues or postgraduate courses.

The students felt enthusiastic about the group work. They preferred the later problem-oriented semesters with their better possibilities to decide the content and organization of the project work and their better scientific and technological tools to solve the problems. But the formation of groups was found to be a difficult and sometimes painful process.

The balance with 50% project work, 25% project-oriented courses and 25% general courses was assessed as perfect.

Also the demands of the curriculum were assessed to be sufficient, but it was judged too diffuse by a minor part of the students. The students assessed the technical coherence in the programme as average.

There was a good overlap between the supervisors' qualifications and the qualifications the students wished them to possess, such as willingness to advise, engagement in and mastery of the subject, and the ability to provide precise and clear explanations. Only at the last point many of the supervisors failed the students grading.

Finally, the examination system with a written project report to be presented and defended by the project group, was judged good by the students as well as our graduate engineers, external examinators and the international panels.

To conclude, the combination of problem-oriented and project-organized education in Aalborg has proved to be an effective educational system, which produces readily adaptable graduates with strong qualities in problem-solving, communication and general technical knowledge. The weakness of the problem-based education is the students' lower load of textbook knowledge and methodology.

SAMMENFATNING

Sammenfatning

aau's projekt-organiserede studier blev introduceret i 1974 som et led i reorganiseringen af universiteterne i begyndelsen af 1970'erne.

De danske projekt-organiserede uddannelser har vist sig at være et enestående eksperiment, der har vakt stor opmærksomhed og aftvinger respekt i udlandet. Ingen andre ingeniøruddannelser gennemfører projekt-organiseret undervisning så konsekvent og ingen andre steder er det lykkedes at integrere teori i projektarbejdet i en sådan udstrækning.

Denne bog beskæftiger sig især med de teknisk-naturvidenskabelige uddannelser. Her anvendes det første år på at lære at arbejde projekt-orienteret, samtidig med at de studerende lærer den nødvendige grundlæggende viden indenfor matematik, fysik, kemi, sprog og forholdet mellem teknik og samfund.

De næste 2 år er de studerendes projektarbejde overvejende konstruktions- og designorienteret. Projektarbejdet underbygges af de nødvendige kurser og forelæsninger. Det er her, de studerende opnår deres "know how" viden.

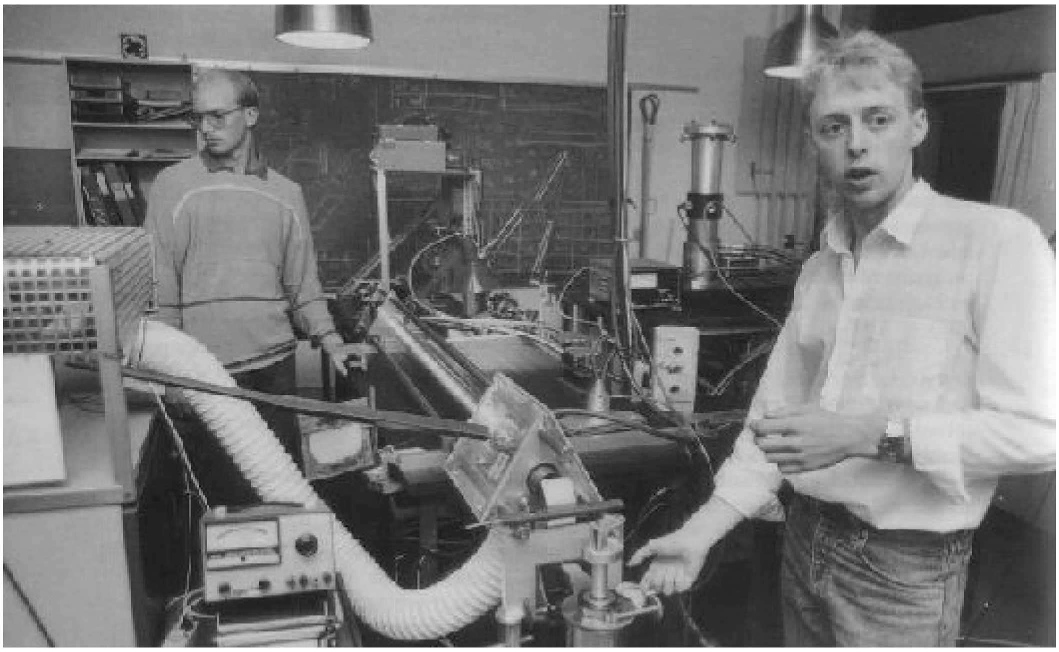
De sidste 2 år i kandidatuddannelserne er projektarbejdet overvejende problem-orienteret. Her arbejder de studerende med at behandle hidtil uløste faglige og videnskabelige problemer. Dette underbygges ligeledes af de nødvendige kurser og forelæsninger. Det er her, de studerende opnår deres "know why" viden.

Hvert projekt varer et semester og alt i alt anvendes halvdelen af tiden på projekter og halvdelen på kurser. Kurserne er igen ligeligt fordelt mellem kurser, der retter sig mod projektet, og generelle kurser.

Da det er problemerne, der er udgangspunktet, skal løsningerne til et projekt ofte hentes fra flere discipliner på en gang. Herved lærer de studerende naturligt at arbejde tværvidenskabeligt. Samtidig arbejder de studerende med aktuelle uløste problemer indenfor faget, hvorved det sikres, at det er den nyeste og mest aktuelle viden, de studerende opnår.

Den projektorienterede uddannelse har vist sig at have en stor omstillingsevne. Dette gælder dels internt på universitetet, hvor problemorienteringen medfører, at uddannelserne konstant ændres i takt med nye videnskabelige og teknologiske landvindinger, og dels eksternt, hvor kandidaterne har vist sig at være dygtige til at give sig i kast med nye ukendte problemer og med andre fagområder end dem, de har beskæftiget sig med i studiet.

Den projektorienterede uddannelse kræver både en intensiv vejledning og arbejdspladser på universitetet til hver af projektgrupperne. Den stadige fornyelse af kurserne, som problemorienteringen tvinger igennem, medfører endvidere, at de kurser, der retter sig mod projekterne, til stadighed må fornyes, ofte hvert år. Alt i alt medfører dette, at studieformen bliver meget ressorucekrævende. Til gengæld giver den også en effektiv indlæring, 80% af de studerende består deres eksamen, og det sker på den normerede studietid. Statsrevisorerne har vurderet det til at være Danmarks mest effektive ingeniøruddannelse.



Men kan uddannelsernes indhold også leve op til forventningerne?

Dette spørgsmål kan besvares på baggrund af en række evalueringer af de danske ingeniøruddannelser. Disse evalueringer blev foretaget såvel af to internationale ekspertpaneler som af de eksterne censorer, kandidaterne, deres arbejdsgivere og de studerende.

Alle evalueringerne pegede samstemmende på, at der ikke var hverken kvalitets- eller niveauforskelle mellem civilingeniører fra aau og DTU eller mellem akademiingeniører fra aau og DIA. Men evalueringerne afdækkede også væsentlige forskelle i profilen for ingeniører fra aau og DTU/DIA. Forskelle, der blev vurderet at være komplementære og dække forskellige behov såvel hos de studerende som på arbejdsmarkedet. Denne bredde bedømte et internationalt panel at være en stor styrke for Danmarks ingeniøruddannelser.

aau-ingeniørerne blev vurderet som relativt stærkere indenfor problemløsning, kommunikation, samarbejde og generel teknisk viden, medens DTU/DIA-ingeniørerne blev vurderet som relativt stærkere indenfor paratviden og faglig metode.

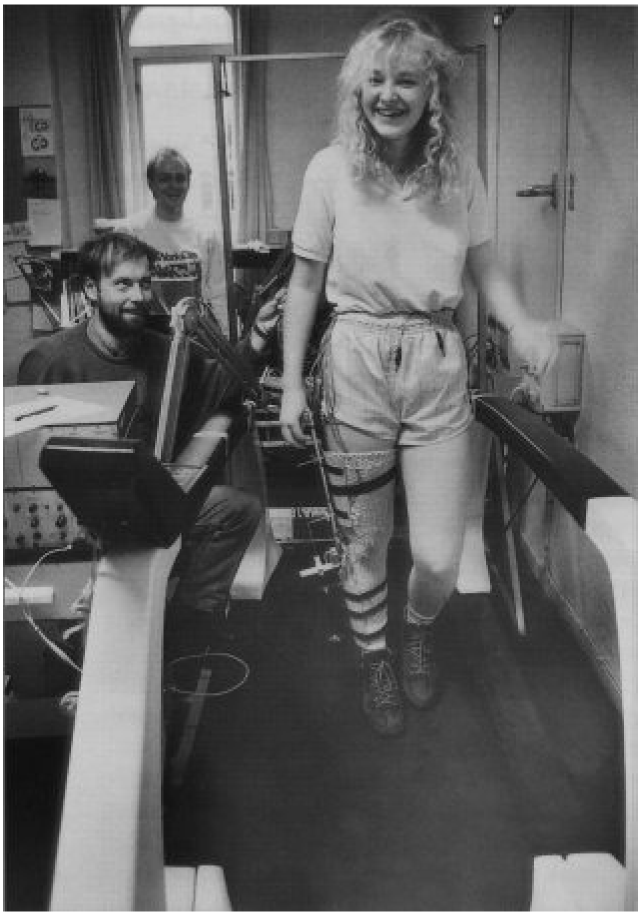
aau-ingeniørerne havde ingen problemer med deres første arbejde og de følte sig fortroligt med dette efter 3 måneder. Der var dog en mindre del af anlægs- og bygningsingeniørerne, der havde oplevet problemer med praktisk erfaring, da de startede i deres første job, medens en mindre del af de øvrige ingeniører havde oplevet problemer med organisationskulturen på deres første arbejdsplads. Der var nærmest fuld overensstemmelse mellem den sammensætning af viden og erfaring, aau-ingeniørerne havde erhvervet i deres studie, og den viden og erfaring, de anvendte i deres efterfølgende ansættelse. Den eneste forskel var lidt større vægt på videnskabelighed og teoretisk ingeniørviden på universitetet og lidt større vægt på økonomi i erhvervslivet.

Iøvrigt vurderede de færdiguddannede ingeniører, at databehandling og fremmedsprog var vigtigere for deres daglige arbejde end de naturvidenskabelige grundfag.

Projektarbejdet viste sig at give ingeniørerne en ballast for livet. Tre år efter aau-ingeniørerne dimitterede, svarede de, at projektarbejdet fra universitetetstiden var hovedkilden til den viden, de anvendte i deres daglige arbejde. Kurserne fra studietiden og senere erhvervet viden og erfaring fra ansættelse, kollegaer og videreuddannelse var derimod kun af lille betydning.

Evalueringerne viste, at de studerende var entusiastiske omkring gruppearbejdet, også selvom de fandt, at gruppedannelsen var en svær, og ind imellem smertefuld proces. De studerende fandt at gruppepresset var en positiv erfaring - der samtidig medvirkede til den høje gennemførelsesprocent. De studerende satte i øvrigt større pris på projektarbejdet i den senere del af studiet, hvor problemorienteringen og det friere projektvalg gav dem bedre mulighed for at bestemme indhold og organisering af projektarbejdet samtidig med, at de havde bedre faglige forudsætninger.

I alle evalueringerne blev balancen med 50% projektarbejde, 25% kurser, der rettede sig mod projektet, og 25% kurser, der rettede sig mod den samlede uddannelse, vurderet som ideel. De studerende ønskede dog bedre tid til individuel fordybelse. Kravene i studierne blev vurderet som passende, men en mindre del af de studerende fandt, at kravene var for diffuse. Den tekniske sammenhæng i studierne blev vurderet at være et sted mellem god og begrænset.



Begge disse forhold viser en svaghed ved det problem-orienterede studies krav om konstant opdatering og fornyelse af det faglige indhold.

Der var god overensstemmelse mellem de studerendes vurdering af lærerstabens kvalifikationer og de kvalifikationer, de studerende ønskede lærerne besad. De højest estimerede kvalifikationer var villighed til at rådgive, fagligt engagement, faglig dygtighed og evnen til præcise og klare forklaringer. Kun på det sidste punkt levede lærerne ikke op til de studerendes ønsker.

aau's evaluerings- og eksaminationssystem med aflevering af projektrapport, mundtlig fremlæggelse af projektets baggrund og indhold, forsvar for projektet og eksamination af de studerende, alt i grupper med individuel bedømmelse, blev vurderet som godt i alle evalueringerne. Den første internationale evaluering, der var meget fascineret af systemet, påpegede dog, at en mere nuanceret bedømmelse af den enkelte studerende kunne styrke uddannelsens internationale omdømme. Dette har ført til en opstramning i evalueringssystemet, som blev vurderet som godt i en efterfølgende evaluering.

Alt i alt har aau-ingeniøruddannelsens kombination af problem-orientering og projekt-organisering vist sig at være et effektivt uddannelsessystem, der producerer kandidater på højt internationalt niveau.

aau-ingeniørernes styrke ligger indenfor problemløsning, kommunikation, samarbejde og generel teknisk viden, medens de traditionelle ingeniørers styrke ligger indenfor paratviden og metodologi.

PROBLEM-ORIENTATION AS A LINK BETWEEN THE ACADEMIC AND THE PROFESSIONAL WORLDS

But who is to guard the guards themselves?

Plato

Once there had been a marvellous party among the Guards in ancient Athens. They got drunk, began to disturb law and order and get into combats with the citizens of Athens. But what were the citizens to do, since it was the persons who had been commissioned to keep law and order who disturbed it?

This led Plato to the famous quotation "who is to guard the guards themselves?"

In modern education we have a similar problem: "Who is to teach the teachers?". We have teachers who have been commissioned to train the next generation, but with the fast development of knowledge how can we be sure that teachers teach the students the latest knowledge in order to keep the graduates up-to-date?

It is to this question the problem-oriented project work is an answer.

In the old battle between those who think they possess knowledge - the sophists - and those who seek knowledge - the philosofists - problem-oriented project work stands besides Socrates and the other philosophers

It is the attempt to solve the current problems within e.g. engineering which guides the students together with the teacher to the areas of knowledge and theories which are essential.

At Aalborg University we have developed such a problem-oriented project-organized educational system which has operated successfully for the past twenty years. This book deals with a description of the system and our experience with it.

PROFESSION, RESEARCH AND EDUCATION

The educational system at Aalborg University was developed to ensure a dialectic relationship between academic theory and professional practice. This was to ensure greater adaptability of application between theory and practice for the purpose problem-solving. The theoretical problems make up the engine which operate this educational process and ensures that the knowledge of our graduates is up-to-date.

A successful educational system depends on a comprehensive interplay between profession, research and education. The problems which are to be found in professional practice and research are the best guides for the learning process. They are the adhesives which bind practice, research and education together, and which make the result stronger than the single components.

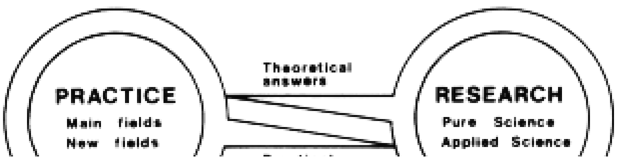


Figure 1. The dynamic model of the relationships between practice, research and education.

Practice may be defined as specific fields, or tasks, within society, conforming professional functions which are carried out by academically trained persons, e.g. civil engineers.

In a society of increasing complexity, one has to continually face new problems and new challenges in practice. The technological development, computer integrated manufacturing, expert systems and genetic technologies are examples of these demands within our fields or within our practice. The specific tasks within the various professional functions are also changing and new areas are appearing.

The traditional way in which to deal with these challenges is in-service training, professional seminars, the publication of articles, etc.

This method of development is a slow process. The answers, or even the problems themselves, may no longer be of current relevance when the solutions are found, while society is still developing new problems which require new solutions.

We have to face the fact that traditional methods are no longer always adequate. The answers are no longer to be found within the profession itself.

In order to make improvements, we must involve research and education in the development process so that we get a dynamic interplay, as shown in Fig. 1. We need research to produce theoretical answers, and we need an interplay with education in order to produce graduates who are capable of producing practical answers, by applying new knowledge and skills to deal with the new and yet unknown problems of the future.

APPLIED SCIENCE

Applied Science deals with problems arising from practice.

Applied Science is characterized by the imperative of the problem, i.e. the problems in which Applied Science can be involved are those which can be observed in the "real world" which lies outside the world of Pure Science.

Applied Science is problem-oriented. The problem-oriented scientific process can be described as shown in Figure 2.

As a basis for an attempt to attain a conscious perception we have a number of impressions, assumptions and theories built into our language, culture, professional practice and way of life.

It is those impressions, assumptions and theories which guide us in our professional lives, but we can meet situations in which they are inadequate, and then practical problems can arise.

The practical problem can be a symptom that something is wrong with our theories and assumptions, and thus the practical problem produces a theoretical problem as to why there is a practical problem (Adolphsen 1985).

The causes of the problems which are experienced in practice outside the world of Pure Science, must be sought by means of Applied Science. The theories and methods best suited to give a scientific explanation are chosen from among all available scientific theories and methods. There are no cognitive, theoretical or methodological reasons to limit the choice of theories and methods in the problem-oriented research process.

The solution to a theoretical problem is a new theory which explains the problem. If the theoretical explanation of the causes of the practical problem can provide a solution to it, there is strong evidence that the theory is valid.

Thus it is possible to compare theories according to their ability to solve practical problems.

What is described is the dynamic interplay between practice and research, where practice produces practical problems (inter alia) and research produces theoretical possibilities and answers; i.e. they produce new knowledge.

Whereas Applied Science is influenced by the restriction to the problems which are recognized in practice outside the scientific world, and by the freedom to choose which theories and methods will be applied to solve the problems in question (Kjersdam 1987), Pure Science is, in contrast, influenced by the restraints of the paradigm on the choice of theory and method by the researcher, and by the licence of academic research, to choose to which of the puzzles of the paradigm a solution should be attempted (Kuhn 1962).

Where as Applied Science pursues the systematic study of theoretical problems which originate outside the scientific world, Pure Science pursues systematic testing of the extent of the validity of theories and methods (Great Science) and operates in the realms of reality and abstraction, searching for new paradigms (Grand Science).

It is in this dialectic interplay between Applied and Pure Science that scientific progress is achieved. This is where Applied Science compels the development of Pure Science to progress within areas in which practical problems exist, which cannot be explained within the existing assemblage of theories and methods. As a result, Applied Science develops by having new theoretical and methodological possibilities which are offered by steps forward in Pure Science.

The comprehensive dynamic interplay, extending from the experience of practical problems to the discovery of new paradigms, and which forms the basis of scientific progress, is shown in Figure 3.

EDUCATIONAL INNOVATION

This scientific interplay constantly produces new paradigms, new theoretical possibilities, new theoretical explanations and new practical solutions, but it often takes many years to achive the innovation of these new inventions.

Therefore, if we want to produce graduates with relevant qualifications and experience with the problems they will be expected to deal with after leaving the University, it is necessary that the faculty is composed by active researchers. If we socialize the students in an outdated paradigm, it will take many years, to alter their methods of working after graduation, if this is possible at all.

This indicates the need for integration between education and research.

To pursue this aim, it is essential to have a curriculum which has great internal adaptability in an innovative form. The curriculum must be quickly changeable to make it possible always to be able to deal with professional problems and their current implications to society.

The internal adaptability of the curriculum makes it possible to test partial results from research from the faculty or elsewhere, without delay, in education, which should provide valuable feed-back for further research. We also have the possibility of dealing with theoretical problems in education by trying to solve the problems during the process of integration of education and research.

Traditionally higher education has been focused on rule-based disciplines with independent identities in their own contexts.

In the discipline-oriented education, the special disciplines and theories, which are considered necessary/relevant for the specific subjects, are taught by means of set textbooks and lectures. The students become experienced in the use of these disciplines and theories through the exercises and case work which support these theories.

The aim is specific knowledge in certain fields and standard solutions to known problems.

In this tradition all undergraduates in the same study programme follow virtually the same curriculum and - hopefully - acquire the necessary and sufficient knowledge in order to carry out certain specific functions in society. This system functions reasonably well in a stable society where the individual functions and tasks are reasonably standardized and where there is no awareness that the situation should be otherwise.

Problem-oriented education, however, is based on working with unsolved, relevant and current problems from society/real life, e.g. the engineers' professional activity in an environment where solutions to real problems are sought.

By analyzing the problems in depth the students learn and use the disciplines and theories which are considered to be necessary to solve the problems posed, i.e. the problem defines the subjects and not the reverse.

Organizing problem-oriented education as project work allows groups of students to choose problems and work with them, learning from each other.

The individual student - hopefully - acquires the necessary basic knowledge and information by means of literature and lectures and, through project work, develops the ability to formulate, analyze and solve relevant problems. In principle, it can thus be ensured that the graduates have obtained the experience to enable them to solve also the unenvisaged problems of the future.

How educational progress is to be achieved will now depend on the degree of awareness of the necessary dialectics between discipline and problem-oriented education.

The disciplines and their related theories are necessary for the graduates' fundamental academic knowledge, and they are needed in order to provide basic professional knowledge for the project work.

On the other hand, problem-oriented project work is necessary in order to understand the inter-disciplinary interplay existing in the problems of real life, and to enable the graduates to deal with the new and unknown problems which will appear in the future.

The aim is a broad insight into and understanding of the connections between different fields and skills, in order to be able to function in an ever-changing society, which is becomming increasingly more complicated.

The problem-oriented educational system involves professional problems as they appear in real life. The process from when a problem appears in practice and until the theoretical and practical answer are found and implemented in practice takes time.

If we wish to increase the speed of this process, the students have to be provided with great external adaptability, in an innovative form.

This means that the graduates must be in possession of comprehensive knowledge of the development of theoretical and methodological tools in order to solve new and complex problems which will appear in the future. The graduates must be able to cope with the structural changes within the existing professional fields and, perhaps, to form new areas of practice.

> *Parts of this chapter were presented in earlier versions at the International Federation of Surveyors (FIG) Symposium on University Education for Surveyors in Madrid 1988 and The Second World-Congress on Engineering Education (UNESCO/MEES/SECC) in Hangzhou 1990.*

PROJECT-ORGANIZED EDUCATION AND HOW TO IMPLEMENT IT

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

Project-organized education is multidisciplinary by nature. It can be divided into two main groups, design-oriented and problem-oriented education. Design-oriented project-organized education deals with practical problems in constructing and designing on the basis of a synthesis of knowledge from many disciplines. We are dealing with KNOW HOW. The problem-oriented project-organized education deals with the solution of theoretical problems through the use of any relevant knowledge, whatever discipline the knowledge derives from. We are dealing with KNOW WHY.

In the programmes in engineering and science at Aalborg University we use both kinds of project-organized education. In the undergraduate studies the project work mainly involve the design-oriented approach, while the graduate studies mainly involve with the problem-oriented approach.

ORGANIZING THE CURRICULUM INTO THEMES

In order to provide for the use of project work as a basic educational element the curriculum has to be organized in general subjects or "themes", normally covering a semester. The themes chosen in a programme must be generalized in such a way that the combination of themes will meet the aim and constitute the professional profile of the education.

The themes should provide for studying the core elements of the subjects included (through the courses given) as well as explore (through the project work) the application of the subjects in professional practice and society. Therefore the themes have to be chosen and organized according to the following requirements:

- The themes must constitute the professional profile of the curriculum.
- The themes must be organized in such a way, that increased knowledge and cognition can be obtained with progression during the study process.
- The themes must have a general expression in order to provide for a broad range of subjects for the project work carried out on the specific theme.
- The themes must have a delimited professional approach in order to provide for teaching the necessary disciplines through courses and for fixing the professional perspective of the project work.

If these demands are fulfilled the structure of the study programmes will contain the possibility of rapid adjustment of the content of each semester according to the technical and professional development in society. This means that the total curriculum will provide for great internal adaptability in order to ensure that the courses as well as the project work will deal with the most topical problems.

The curriculum for educating chartered surveyors in Denmark may be used as an example to illustrate the selection of themes as well as to explain the adaptability of the educational model.

The curriculum as shown in Figure 4 is divided into 4 phases:

The first phase, 1st and 2nd semesters, includes one year of basic studies within Technical or Social Science. The studies include courses in the fundamentals (mathematics, physics, chemistry, computer science, foreign languages etc.), and the basic skills for carrying out problem-oriented project work are trained. After passing the examination of this first year, the students have to decide between several options of programmes, among which is the programme for chartered surveyors.

The second phase, the under-graduate studies at 3rd to 6th semesters, includes two years of studying the main professional areas for surveyors. The themes constitute the main professional profile consisting of Land Use Planning, Land Surveying, and Cadastral Management.

The themes then provide for teaching the necessary disciplines through courses and for training the professional functions through the project work. Therefore this phase is characterized by a "know-how" approach. The aim is for all students to acquire the same basic knowledge and skills within the three main professional areas.

After passing the Undergraduate examination at the end of the 6th semester, the student can continue for two years of specialized studies for a Master's degree.

On the basis of the common knowledge established during the second phase, all postgraduates will have the possibility of obtaining a licence, qualifying them for carrying out cadastral work in a private practice.

In the third phase, the graduate studies at 7th to 9th semester, the curriculum provides for the possibility of specialization. Within broad limits the students can choose their themes for obtaining a specific professional profile and choose their problems within the themes for obtaining special knowledge.

The themes in this third phase of the curriculum therefore have a more scientific approach based on "know-why". The themes will provide for teaching the necessary theories and knowledge within the specific professional areas, and for training the methodological skills of problem analysis and application.

The fourth phase, the 10th semester, is only for preparing the master's thesis which is written as project work dealing with a problem chosen by the student groups themselves.

The adaptability of the educational structure may be explained under three headings:

- The adaptability of the individual theme. This means that the focus on subjects presented in the courses and dealt with during the project work are easily updated or changed according to the current scientific and professional development. The subjects and contents of the lecture courses given will be planned in advance before starting the semester, and will then reflect the most topical issues.
- The adaptability of the entire curriculum. This means that the focus of the themes in total may be easily adjusted according to the needs and development of professional practice. (E.g. we are now planning to integrate the subjects of Land Information Systems at 7th semester into the basic disciplines and project work in

the second phase of the curriculum. This integration will allow for establishing two themes at 7th semester: Engineering Surveys and Property Economics. At the technical specialization the themes at 8th and 9th semester will then be Mapping and Management of Geographical Information Systems respectively. These changes will be consistent with the current technical development and are easily implemented in the curriculum).

- The adaptability of the graduates. This means that each individual graduate will possess specialized knowledge within one of the three main areas (Surveying, Land Management or Urban and Regional Planning), but due to the basic knowledge established during the second phase of the curriculum, and due to the methodological skills established during the project work, the graduates will also possess the insight to understand and adapt the interaction between the three main areas in total. (E.g. the graduate may have specialized within the area of Land Management, but may be employed for engineering surveys). In this way the graduates possess the external adaptability needed for dealing with the challenges of a rapidly changing labour market, and will even be able to develop new fields of professional practice when they possess knowledge which is new to the profession.

RUNNING THE THEMES

Each semester has a basic structure containing, in principle, an equal distribution of lecture courses and project work. But the study-time is dominated by lectures at the beginning of the semester and by project work at the end. The distribution during a semester is shown in Figure 5.

Each course is normally divided into 6 lectures, each lasting half a day. This means that the minimum pedagogical unit is half a day, morning or afternoon. Time is thus secured for the absorption of the subjects presented and for establishing the relevant connection between lectures and project work.

There are two types of lecture courses, general courses and project courses. The aim of the general courses is to establish the necessary fundamental and general knowledge for the graduates.

The aim of the project courses given is to deal with the theoretical and professional contents of the theme.

The professional and discipline-oriented approach dominate at the lecture courses given in the undergraduate studies, while the theoretical and scientific approach dominate the courses given at graduate studies. The courses will have to establish the necessary knowledge and skills for carrying out the project work within the frame of the theme. In the curriculum 50% of the time is spent on project work, 25% on courses related to the project and 25% on general courses related to the curriculum.

The aim of the project work is "learning by doing" or "action learning".

The professional skills are established during the design-oriented project work, which is dominating at 3rd to 6th semesters.

Scientific cognition and methodological skills are established during the problem-oriented project work at 7th to 10th semesters. Also the ability to present independent conclusions, and the ability to complete the project in time are practised. In fact the process of the project work at this stage is very similar to the problem-solving process both in research and in practice.

The project work also has pedagogical importance. Each student must be able to explain the results of his studies to his colleagues in the project group and to the supervisor as well. This demand may be the clue to professional and theoretical cognition. Knowledge is only really established when one is able to explain this knowledge to others.

In traditional education the students mainly restore knowledge presented by the teacher. But using the project-organized model knowledge and cognition are established during discussions between the students in the project group, and often without the personal appearance of the supervisor.

The project work normally concides with a semester. At the start of the semester the theme in question is presented during key lectures and general discussions. Recent projects written during previous semesters may be presented for inspiration, and the students will be encouraged to discuss potential subjects for the project work according to their professional interests.

The students will establish preliminary groups for clarification of the possible subjects to be presented at the periodical plenary sessions during the first three weeks of the semester. The subjects for the project work will then crystallize through discussions between the students and their potential supervisors.

Also the process of formation of the project groups will come to an end during this period of introduction. This process can be problematic, but normally the students will find the solutions according to their professional and personal preferences and ambitions. Here it must be noted that the students will have a common interest in getting started and they will share the responsibility of finding a solution which is satisfactory for all students at the semester. On average the groups will be of around 4 students. Also individual studies are possible, but this is clearly an exception. Each group will normally have their own room at the university for carrying out the project work. The rooms are equipped with computer networks connected to internet.

The supervising teachers on the theme are appointed according to professional interests and skills before the semester begins. The distribution of the supervisors between the groups will crystallize during the process of finding the subjects and forming the project groups. The students may have some professional or personal interests and wishes concerning this distribution, but the teachers will make the final decision.

THE PROCESS OF THE PROJECT WORK

As explained above we can identify two different types of project work: The design-oriented and the problem-oriented.

The design-oriented project work will normally be used for training the necessary knowledge and skills within the disciplines presented. The process and the content of the project work will therefore be organized as fixed standards in advance. The supervisor will teach the students what to do, and the capability of doing it will be trained through the project work.

The problem-oriented project work is used mainly in the last part of the curriculum for establishing scientific cognition within the study fields chosen by the students.

The project work here is centred on exploring and handling a problem with an unknown solution. The cognitive dimension leads to questions like: Why is it so....? How come...? What is the meaning of...?

The process is based on problems as a starting point and the character of the problem will then determine the choice and disciplines, theories and methods needed for analyzing and solving the problem.

The process will mainly be controlled by the students themselves. The choice of theories and

methods will be supervised by a researcher, and the product will be evaluated at the examination at the end of the semester.

The project work process will normally run through the following steps:

Problem analysis: Here the problem is presented, described and assessed in a broad context. The relevance of the problem is evaluated and strategies for standard solutions are worked out. The problem is now to be finally formulated. The project work at this stage is based mainly on discussions, studies of relevant literature and maybe preliminary interviews with keypersons in order to confirm the relevance and reality of the problem posed.

Problem-solving: Here the criteria of evaluation are laid down, using relevant scientific theories, and possible ways of solving the problem are evaluated. According to the nature and complexity of the problem, there may be a need for further development of existing theories or even for developing new theories.

The problem may be divided into partial subjects to be investigated separately, and in detail, using relevant scientific methods. Here the supervisor has an important task of guiding the choice and methods, similar to the research process. The problem posed may call for the use of case-studies, experiments, quantitative or qualitative empirical investigation, logical analysis and construction of concepts, etc. Here the point is that the choice of methods must be explainable and acceptable according to the posed problem.

The results of the investigation are evaluated, compared to the consequences, and again compared to the posed problem. At this stage the project work is characterized by professional absorption through lectures, methodological analysis, field work, etc.

Report: Here the group has to review the project, set up conclusions, and complete the project documentation. The report will then present the studies carried out. It will prove the knowledge established and also how this knowledge was produced. At the final stage the project work is mainly characterized by the tension of approaching deadline; - like in practical engineering.

Through the curriculum the project groups deal with still more advanced problems and the level of problem-solving progresses towards the thesis.

In many of our master's programmes, one of the project reports is replaced by a scientific paper following the norms of international scientific journals.

EVALUATION AND EXAMINATION

The capability and the quality of the educational system is evaluated within the educational system itself. This is done by a system of internal monitoring.

Internal monitoring serves the purpose of quality management with regard to the relevance and quality of the courses as well as the quality of the entire semester concerning supervising, organization and ressources. A monitering report is presented by the students in co-operation with the teachers. This report is assessed by the Board of Studies and used for preparing and improving the same theme the following year.

A system of external examination at the end of each semester serves the purpose of external professional and academic control. One or two external examiners are present, representing the professional world/industry, and/or the academic world/universities. The examination system thus allows for the control of professional relevance and academic standards as well as control of the entire educational system. At the more important examinations including the thesis, the examiners are appointed from industry and other universities by the Ministry of Education. Examiners at the remaining examinations are appointed among the university's faculty.

The emphasis at the examination is on the evaluation of the project. The project group submit a written report of 50-150 pages one to two weeks before the examination. At the examination, the group make an presentation of the project, where each member of the group presents a part of the project. Often they also make a poster. This is followed by the defence of the project report. The evaluation is conducted by the teacher appointed as the group-supervisor. Such examination normally lasts half a day.

The purpose of the defence and the following discussion is to examine the knowledge possessed by the individual student about the project and the connected academic disciplines as well as their broad insight and professional knowledge. In the session in which the report is presented and defended, the members of the project group are examined in the project courses in connection with the examination of the report.

The examination of the general courses is normally held at the end of the semester, in which they are lectured. This examination does not differ from the examinations at other universities. At the examinations of the projects and the project-related courses, the students are graded, while the general courses are mainly assessed on a pass/fail basis.

The process of the project work and the selection of theories and methods are controlled by the students, but the standards used at the examinations and the criteria of excellence are certainly not under the influence of the students. These standards and criteria may be more difficult to define precisely and communicate to the students beforehand than in the traditional learning processes with standard solutions to standard problems based on textbooks.

On the other hand, the documentation of the knowledge possessed by the students is provided in a far better way. In the project-oriented model all marks on the diploma can be documented by the reports and assessed by trade and industry.

THE ROLE OF THE SUPERVISOR

The supervisor in the project-organized education model has to face other demands than the teacher in traditional education. Pedagogical skills for guiding the project work as well as skills for guiding the use of scientific theories and methods for analyzing the problems are essential. The supervisor has the responsibility of guiding the students to complete the project work in time, and in a defensible way according to methodological and scientific requirements. Of course normally the supervisor will possess a broad professional insight. But if the supervisor is not familiar with the professional subject, a second teacher should be attached to the group as professional deputy supervisor. This means the traditional role of the teacher is changing from: Lord at the lectern, to coach on the side.

The teacher also has to face the demands of constantly changing the contents of the courses, or developing new courses, according to the development of the profession, new research results and the changing problems within society. These demands may be seen as a challenge rather than a problem. They also ensure the continous professional development of the faculty. But a problem may arise regarding the distribution of the limited resources at the university since much preparation is required.

The project work which is carried out by the project groups, promotes strong motivation for research by the teachers. In the project work, the problems and the choice of theories and methods are discussed with the supervisor. Many essential problems can be defined through the project work and continued in the research which is carried out by the supervisor. Many of the student projects may be based on the current research activities of a teacher. The project groups may e.g. analyze partial problems, theoretically or empirically, and thus contribute to the development of knowledge in fruitful co-operation with the teacher.

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

Parts of this chapter were presented in earlier versions at the International Federation of Surveyors (FIG) XVIII International Congress in Toronto 1986, the Second Symposium for Engineering Deans and Industrial Leaders (UNESCO/FEANI) in Paris 1991, FIG Commission 2 workshop on Educational Challenges in Aalborg 1993 and FIG XX International Congress in Melbourne 1994.

EVALUATION OF THE AALBORG EXPERIMENT

The activity of understanding is,
essentially, the same as
that of all problem-solving

Karl Popper

One must expect that the consequences of this educational model is that the new graduates are less experienced in solving standard everyday problems as they will appear in future employment. On the other hand, they are expected to be much better qualified to undertake large and complicated tasks, to combine insight from different fields, to analyze new problems and to make themselves acquainted with new fields to which the problems of practice are related.

The aim is a broad insight into and understanding of the connections between different fields and skills, in order to function in a society, which is becomming increasingly more complicated. In principle it can thus be ensured that the graduates have obtained the skills and experience to enable them to solve also the unknown problems of the future.

But some scepticism may be displayed: will the graduates be able to face the demands of the profession? Will the new graduates reach the academic standards? We will try to answer these and other questions through the evaluation of our educational system.

INTRODUCTION TO THE EVALUATION

The novel problem-oriented project-organized studies at Aalborg University were recently recognized as a real innovation in higher education as important as the Open University concept in the United Kingdom.

This recognition was given by an international panel, which had been commissioned by the Danish Ministry of Education to evaluate the international competitiveness of the Danish electrical and electronic engineering educations. This evaluation included evaluation of the project-organized studies in Aalborg and a comparison with traditional university education (Arnbak, Boom, Langmaack and Nelson 1993).

In connection with this evaluation a questionnaire was sent to a selected number of employers within the electrical and electronic industries (N=43). The purpose was to assess the employers' satisfaction with the qualifications of the engineers. The response was not satisfactory, since only 37% completed the questionnaire (Kümmel 1993).

Another international evaluation process was carried out by an international panel, which had been commissionned to evaluate the Danish civil and construction engineering educations (Christophersen, Coupe, Lenschow and Townson 1994).

In connection with this evaluation a questionnaire was sent to all external examiners in Denmark within civil and construction engineering. The response was 55% (N=801). They were asked to assess the strengths and weaknesses of the students, the examinations and the relevance of the educations in relation to the labour market outside the university. (Evalueringscentret 1993).

Also a survey of the graduate engineers was conducted. A test sample of 353 civil and construction engineers, graduated in 1988 or 1991, was selected and interviewed over the phone. The response was 63% (PLS Consult 1993).

Besides this evaluation the university itself has initiated several evaluation processes. One of these was carried out by the Faculty of Technology and Science at Aalborg University in 1989.

This evaluation included a questionnaire sent to all students who had graduated from the faculty in 1986 with a degree in Engineering. The response was 74% (N = 339). This evaluation also included interviews arranged for a random sample of graduates and employers.

The purpose was to determine, on the basis of 3-4 years of experience as graduate engineer, what knowledge and experience from the studies were being used in practice, whether the project-organized education provided the necessary knowledge and experience for the professional practice, whether there were difficulties arising from the project-organized education in the employment and whether the graduates and employers were satisfied with the Aalborg engineering programmes (Jensen and Wagner 1990).

At the same time evaluation was also carried out by the University, including a questionnaire sent to all the students at the undergraduate level at 5th semester and at the graduate level at 9th semester. The response among the engineering students was 54% (N = 814).

The purpose was to determine the students' attitude to project-organized education and the contents of the studies, the desirable and assessed qualifications of the teachers and the expectations to the preparation for the profession. Many of the questions were comparable with questions to the graduate engineers (Rasmussen 1991).

The Faculty of Technology and Science in 1991 investigated the interaction between project work and practice by selecting 40% of the academic staff (mainly in mechanical and electrical engineering) and asking them to complete a questionnaire concerning the projects they had supervised in the years 1986-91. This selection included approx. 650 master's theses and 66 PhD projects. The purpose was to determine whether the projects were carried out in co-operation with industry, to assess the possibilities of implementation of the students' solutions in industry and to determine whether the students' solutions were actually implemented.

In 1993 an evaluation of freshmans year was carried out by the Faculty of Technology and Science. This included a questionnaire sent to all the freshmen (responce 70%, N=529), their supervisors (responce 50%, N=60 and external examiners (responce 77%, N=35).

THE PROJECT WORK

The international panel in electrical engineering found that the project-organized approach appears to attract students and they identified students who had chosen Aalborg University owing to its project-orientation.

In the questionnaires the engineering students as well as the professional engineers were asked why they had chosen this particular education.

	Undergraduate	Graduate	Professional
The education and its subjects	41	52	55
Interesting profession	48	40	31
Regular job and high wages	5	3	5
Other	6	5	9
	100	100	100

Figure 7. Reasons for choosing engineering education (%).

There were two reasons for the students to choose Aalborg University, the education and the expectations to the profession, while possibilities of a regular job and high wages were out of focus in the selection process.

Since the professional engineers made their choice in the early 80s and the undergraduates in the late 80s, it is also possible to see some changes from educational to professional focus during the 80s.

In the questionnaire to the freshmen 60% of the freshmen mentioned the project-organized education as the main motivation for their choice of Aalborg University.

The international panels found that the students were very enthusiastic about group work and considered the group pressure to be a positive experience, but they also identified the formation of groups as a difficult and painful process. The freshmen found the co-operation between the students as their main problem in the project work.

The freshmen's involvement with project work was not seen to be as effective as it may in one of the international evaluation reports, since the students did not have the technical knowledge or tools to benefit fully from the experience. On the other hand, it was found that this could be outweighed by the benefits of the early establishment of a group culture, which is the mainstay of the educational programme.

The same assessment emerged when we asked the students to assess the best semester in their curriculum. The assessment showed that the students did not appreciate the first semesters, when they were in lack of technical knowledge and scientific tools.

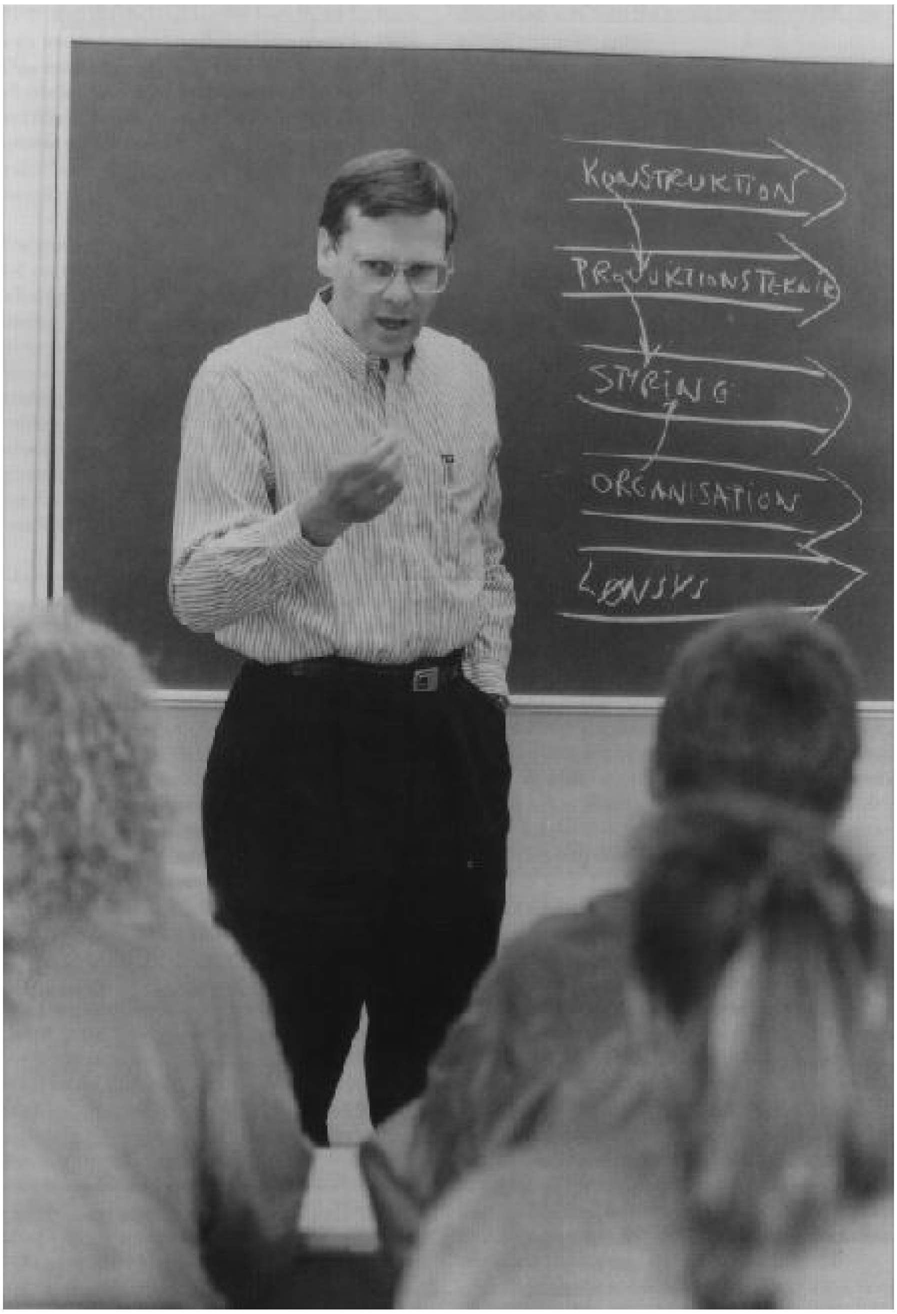
In some way these answers also reflect the students' appreciation of the possibility to decide the contents and organization of the project work themselves, since at the early stages the project work appears to be prescribed exercises, which are used repetitively and thus are not really problem-organized project work in the usual sense.

When we asked the students to assess the possibility to decide the contents of the project work as well as the organization of the process, the graduate students found better possibilities than the undergraduates.

	Undergraduate	Graduate
Excellent	27	45
Good	58	47
Limited	12	7

Bad	3	1
	100	100

Figure 9. The possibilities to decide the content and organization of the project work (%).



Despite these differences, both the undergraduate and the graduate students found good possibilities to decide the organization and contents of the project work.

Concerning the balance between individual work and group work we asked the graduate students to assess the actual balance and express their desirable balance.

The results show that the students want a balance with less group work and more individual work than that which they experience in the programme.

One of the main reasons for choosing Aalborg University was the project-organized programme, but did the contents of the programme come up to expectations?

	Undergraduate	Graduate
Excellent	21	25
Good	67	68
Limited	12	7
Bad	0	0
	100	100

Figure 11. Agreement between the students' expectations and the programme (%).

The result we see is that most of the students found that (to a reasonable extent) the programme comes up to their expectations regarding questions and subjects they wanted to deal with during their studies to and more than 20% found it very satisfying.

This was also one of the findings of the international panels, which found that the students as well as the faculty were supportive of the programme and the organisation.

THE BALANCE AND COHERENCE IN THE PROGRAMMES

We asked the students as well as the professional engineers to assess the balance between project work and courses in the curriculum where half of the time was sent on project work and half of the time on taught courses.

Let us first take a look at the project work.

	Undergraduate	Graduate	Professional
Too much	11	12	15
Sufficient	73	74	78
Too little	16	14	7
	100	100	100

Figure 12. Assessment of the weight of the project work in the programme (%).

The students as well as the professional engineers found the weight of the project work in the curriculum very satisfactory. If we take a look at the taught courses, we will see the same picture.

	Undergraduate	Graduate	Professional
Too much	18	16	11
Sufficient	76	81	76
Too little	6	3	13
	100	100	100

Figure 13. Assessment of the weight of the taught courses in the programme (%).

We also asked the graduate students about the actual and desirable balance between project work and taught courses in the programme.

To conclude, we seem to have achieved the optimum balance between project work and taught courses in our project-organized programme.

The students' actual activities were evenly distributed between project work and taught courses. The distribution was:

- project work 38%
- taught courses 36%
- individual studies 26%

The total work load in a week was 52 hours for each student.

Concerning the demands of the studies on students these were mainly considered sufficient by the students, but often too diffuse.

	Undergraduate	**Graduate**
Sufficient	52	49
Too easy	7	15
Too demanding	9	2
Too diffuse	30	29
Too narrow	2	5
	100	100

Figure 15. The students' assessment of the demands of the curriculum (%).

Anyway, this uncertainty diminished during the years at the university. At 1st semester 70% of the freshmen found the demands in the project work uncertain.

We also asked the students to assess the technical coherence in the programme, and here most of the students found that the technical coherence was somewhere between good and limited. The feeling of diffuseness and lack of technical coherence is one of the weaknesses of the project-organized education's constant demand for innovation and up-to-date knowledge.

	Undergraduate	**Graduate**
Excellent	7	4
Good	46	43
Limited	31	37
Bad	13	13
Don't know	3	3
	100	100

Figure 16. The technical coherence in the programme (%).

The graduate students assessed the balance of the programmes between specialization and general polytechnic subjects as perfect, whereas they found that the attempt to make specialization in engineering by restrictions on the themes within which students can choose their problems and projects limited their possibilities. They wanted more optional curricula.

THE SUPERVISORS' QUALIFICATIONS

The faculty at the university has a traditional academic background, with an emphasis on research. This means that in many ways they are self-educated as supervisors for the project groups, even if they have had some training in project-organized education. The questionnaire showed that they have succeeded at least to a certain degree. Only few were judged to be bad, the main part average and one out of four was judged to be excellent.

The students and professional engineers also assessed the most important qualities the supervisors possessed and the qualities the students wished them to possess.

	Undergraduate	**Graduate**
Excellent	23	24
Average	65	61
Bad	12	15
	100	100

Figure 18. The quality of the supervision in the project work (%).

This assessment was made by the use of Miller's list of ten teacher-qualities registered in an investigation of students' assessment in higher education (Miller 1988).

	Undergraduate	**Graduate**	**Professional**	**Undergraduate**	**Graduate**	**Professional**
	Desirable qualities			**Possessed qualities**		
Willingness to advise	26	28	26	36	40	31
Engagement in the subject	18	20	22	14	18	17
Ability to give precise and clear explanations	17	14	17	6	4	-
Mastery of the subject	15	13	11	19	15	12
Ability to start discussions	8	12	-	8	7	13
Interest in the students	7	5	7	6	5	10
Ability to involve the students	3	4	-	3	2	-
Ability to judge justly	4	2	-	5	7	-

Thorough preparation and planning of the education	2	2	-	1	1	-
Ability to speak to an audience	0	0	-	2	1	-
	100	100	100	100	100	100

Figure 19. The desirable and possessed qualities of the supervisors (%).

There was very good overlap between the profile the students and engineers wished the supervisors to possess, and the qualities the supervisors actually possessed. Quantified, the overlap was 62%. The only important difference in the profiles was that the students wanted more precise and clear explanations than they got from their supervisors. On the other hand, they were ready to accept a lower degree of willingness to advise on the part of the supervisor than the supervisors actually offered.

The questionnaire showed that the supervisors spent 20 confrontation hours in all with the project group every semester, with one supervision or instruction session every week on average.

EXAMINATION AND RECOGNITION

The examination system in Aalborg lays much emphasis on project evaluation with a written project report, poster, a presentation of the project and the project report, all in groups. The graduate students judged the examination system to be somewhere between good and sufficient, while the professionals judged it as good.

	Graduate	**Professional**
Excellent	14	22
Good	33	41
Sufficient	33	27
Bad	17	9
Very bad	3	1
	100	100

Figure 20. Assessment of the project examination system (%).

An international panel found that viewed through traditional university eyes, the time allowed for the provision of the necessary scientific tools through traditional lectures did not seem sufficient for an education well founded on scientific principles. On the other hand, this panel concluded that the system did appear to work.

With the increasing global economy the contents of courses being offered as fulfilling the educational requirements for professional engineers, will come under scrutiny.

The low contents of taught courses in the project-organized programme will seem to dictate a careful review of whether professional engineering guidelines are being met, in order to have the curriculum accepted by the international institutions governing the professional registration of engineers.

Concerning the examination system at Aalborg University the panel found that the traditional university examination system, in which lecture courses are usually graded and project work assessed on a pass/fail basis, is inappropriate in project centered education. It will convey the message to the students that the project work is unimportant and thus undermine the whole project-organized concept.

Instead this panel recommended that the university establishes in place mechanisms for better differentiation between students on the basis of project assessment.

The panel recognized that this recommendation may also have a significant effect on the group dynamics but found it important to strengthen the Aalborg degree in the international market.

If not, they assessed that the university will have a cloud of suspicion hanging over it, that a weak student may hide in a group and that technical leaders will not be fully recognized.

This recommendation has been followed by more emphasis on the individual examination, but still on the basis of the project assessment and with group examinations. Consequently we have experienced that it is possible to have much better differentiation between the students without undermining the project-organized concept.

This is underlined by a later questionnaire to the external examiners in civil and construction engineering. They were asked to assess the evaluation and examination system. The result was a high degree of satisfaction with the system among the examiners. 86% of the examiners assessed the system to be satisfactory, of which 31% assessed it to be excellent. Only 14% found it less satisfactory and none found it unsatisfactory. A special problem is the diploma, which the employers find difficult to understand.

ACHIEVED KNOWLEDGE

If we compare the composition of the knowledge and experience which is achieved and used by the graduate students in their project-organized studies and by the graduate engineers in their professional practice, we will see convincing agreement.

The use of computing, foreign languages, practical knowledge, experimental knowledge, management, economics, knowledge about natural and work environment, resources, culture and society has the same weight at the university as in industry. The only difference is that more emphasis is placed on theoretical engineering and science at the university and more emphasis on economies in industry, but this is only natural in view of the different natures and aims of university and industry.

However the graduate students wanted more economics, management etc. at the expense of pure engineering in the programme.

The surprising result of the investigation was the low priority of the theoretical sciences among engineering graduates. Industrial leaders have always called for more theoretical science in engineering programmes, whereas the investigation showed that computing and foreign languages are much more important to industry.

The investigation exposed great differences between the composition of knowledge and experience used in industry, by a consulting engineer and by an employee in public administration.

In industry, the most important elements were computing, foreign languages and theoretical engineering, while knowledge about the environment, resources, culture and society was less important. Practical knowledge and theoretical science were also given a surprisingly low priority.

For consulting engineers the most important elements were computing, practical knowledge, theoretical engineering and economics, while knowledge about culture and society were of low interest.

In public administration the most important factors were knowledge about the environment and resources, but computing and theoretical engineering were also considered to be important, while foreign languages were not interesting.

An investigation to determine the source of professional knowledge revealed that (after 3-4 years of experience after graduation) approximately half of the engineering graduates considered project work to be the main source, while approximately one fifth were of the opinion that colleagues were the main source.

Only a small number found that systematic educational courses (undergraduate, postgraduate, etc.) were the main sources, although almost half found that the courses in the engineering programme were a partial source.

In reply to where they had learned to apply their knowledge in their professional activity, the respondents said that project work was more important than courses, whilst about one fifth were of the opinion that they had learned more from colleagues.

PREPARATION FOR THE PROFESSION

The concept of the project-organized studies is based on the assumption that during their project work the students also learn to deal with theoretical and practical problems.

This was recognized by the international panels, which found it very gratifying to see that our project centered programme took the view that experience of the practical world was essential in the education of engineers. The panel were convinced that the project-organized education in Aalborg prepared the young people beyond the provision of technical knowledge alone.

They also observed, that the students appeared confident, regularly integrated theory with practice and felt that they were prepared to tackle a wide range of problems in industry. One of the panels concluded that the project-organized education provided graduates that industry could easily adopt.

This is in accordance with the questionnaire, in which a major part of the students and professional engineers felt they were well prepared for the profession.

It is also interesting to see that the graduate engineers had experienced that they were better prepared for the profession than the students felt they would be.

Similarly the graduate students felt they would be better prepared for the profession than the undergraduate students felt they were.

	Undergraduate	Graduate	Professional
Excellent	8	7	20
Good	49	52	65
Limited	27	23	13
Bad	2	5	2
Don't know	14	13	-
	100	100	100

Figure 25. Assessment of the preparation for the profession (%).

If we look at the different fields of specialization, there was general satisfaction with the suitability of the project-organized study as preparation for the engineering graduates for all the fields of the engineering profession. There were some few differences between the fields.

80% of the civil and structural engineers considered themselves to be well prepared, while almost 90% of the mechanical engineers were of the same opinion.

90% of the electrical engineers considered themselves to be well prepared but there was a difference between the electronics engineers of whom almost all were of this opinion and the energy engineers, of whom slightly more than 80% were of this opinion.

The very well prepared graduates were to be found mainly in mechanical and construction engineering.

The basis of these results is the project work in which the students mainly have to deal with theoretical problems from real life, outside the university environment, and interact with practice.

The investigation of the master's theses showed that 62% were prepared in co-operation with private companies or public bodies. 41% of the solutions in these theses were assessed to be suitable for implementation and 20% of the solutions were in fact implemented in industry. 8% of the master's projects which were continued in PhD-projects.

The external examiners from industry and other universities assessed the contents of the civil and construction engineering programmes to be as satisfactory in relation to the labour market outside the university.

72% of the examiners assessed the relation of the programmes to be satisfactory, 17% of whom assessed it to be excellent. 28% assessed it to be less satisfactory, while none found it unsatisfactory.

Concerning the PhD-projects 66% were carried out in co-operation with industry or public works.

In the assessment of the PhD-projects 48% of the solutions were assessed to be suitable for implementation and 39% of the solutions were implemented in industry.

As expected, there was strong interaction with private companies and public bodies during the project work of the students and a considerable part of the students' solutions to the problems they work with in the project work was assessed to be suitable for implementation in industry, increasing with the students' progress in the curriculum.

On this background it is surprising that three out of four students as well as professional engineers assessed the amount of practical experience to be too limited in the programme.

If we compare the balance between theory and practice as well as between fundamental theoretical knowledge and textbook knowledge in the programme, the survey showed that the graduate students wanted more textbook knowledge and practice at the expense of theory and fundamental theoretical knowledge, due to the theoretical problems they deal with in their project work.

However in general the graduate engineers had not experienced difficulties in their first employment.

The graduates had no problems with their theoretical knowledge, neither did they have problems with economics or statutory conditions, or in working with other specialized fields than their own study specialization. Nor did they have problems with their colleagues.

This is emphasized by the fact that less than 1% had changed jobs in the course of the 3-4 years since their graduation, on the grounds of their feeling of professional insufficiency while 13% had changed jobs because of lack of challenge in their employment.

The only difficulties which were uncovered by the survey were that 30% of the civil and structural engineers had felt a lack of practical experience in their first employment, while 20-30% of the other engineers had felt difficulties with organization and the company culture in their first employment.

To conclude, the graduate engineers only felt minor difficulties in their first job and could easily be adopted in industry. This is underlined by the fact that 10% of the engineering graduates felt confident in their first employment after three weeks, rising to 40% after two months and 80% at the end of six months.

PROJECT-ORGANIZED VERSUS TRADITIONAL EDUCATION

The international panels assessed the work conducted by the students during their theses. They found it of a quality equivalent to that of institutions with which Aalborg University is competing internationally.

But the international panel also found that engineers graduating from Aalborg University had significantly different skills when compared with products from a more traditional education.

The project-organized education was found to be regarded as a complementary educational system serving slightly different needs both for the student and the market than those served the traditional education. The emphasis on synthesis and the group culture at Aalborg University generate a graduate more readily adaptable, and thus more directly employable. On the other hand, graduates of a more traditional system with an emphasis on analysis are perhaps better grounded in fundamentals and are more capable of working independently although in general they will require more on-the-job training. Aalborg University was found to put more emphasis on aspects of operational and interpersonal effectiveness compared with traditional institutions focused on fundamental concepts.

This was underlined by the questionnaire to the graduate engineers from Aalborg. They were asked to assess whether at some points the project-organized education had prepared them better or worse for their jobs compared with traditional engineering education.

	Better	**Worse**
Yes	59	36
No	25	51
Don't know	16	13
	100	100

Figure 28. Assessment of engineers graduated in Aalborg of their preparation for their job compared with traditional engineering education (%).

At some points the graduates from Aalborg had experienced that they were better prepared, on other points worse. However, the number of engineers, who at some points had experienced they were better prepared for their jobs than traditional engineers, was twice as large as those who felt they were worse prepared. The areas in which more than 5% of the Aalborg engineers had experienced better preparation were:

- Management and co-operation 29%
- Project work and problem-solving23%
- Communication skills 8%
- General technical knowledge 5%

The areas in which more than 5% of the Aalborg engineers had experienced a worse preparation were:

- Detailed textbook knowledge 10%
- Fundamental knowledge 9%

To conclude, the graduates from Aalborg were stronger in management, co-operation, project work, problem-solving, communication and general technical knowledge, weaker in detailed textbook and fundamental technical knowledge.

A similar conclusion was drawn by the external examiners concerning thesis work and final examinations.

Figure 29. The final examiners' assessment of strengths and weaknesses of civil and

construction engineering students from Aalborg University (aau) and Technical University of Denmark/Denmark Engineering Academy (DTU). (N=114)

The final examiners from industry and other universities assessed the engineering students from Aalborg (aau) to be stronger in problem solving, communication and general technical knowledge, while the traditional engineering students from Copenhagen (DTU) were assessed to be stronger in methodology and detailed textbook knowledge.

There were no differences between the external examiners' assessment of the level of the thesis work and final examinations at the two universities. The examiners found the scientific and professional levels at these examinations most satisfactory at both universities.

A slightly different conclusion was drawn by the employers of the engineers in their evaluation of the Danish electrical and electronics engineers. In a questionnaire (with an unsatisfactory response) the superiors of the employed engineers graduated from the two universities assessed there to be no differences between the general qualifications of the graduate engineers, while the graduates from Aalborg were assessed to have significantly better qualifications in co-operation.

But no other differences were assessed to be significant, including questions in analytic skills, technical knowledge and competence, in dependence and multidisciplinarity, creation of solutions and communication.

Finally no differences at all were found in a survey between the graduate civil and construction engineers.

This survey included both the assessment of the quality, level, content and topicality of the fundamental, scientific and technical knowledge in the programmes at the two universities.

Differences were only observed in the satisfaction with the educational methods and in the level of the courses tought.

More than 90% of the engineers graduated from Aalborg assessed the content of the project work in their education as sufficient and 80% assessed the contents of the lecture courses with a fixed curriculum as sufficient, while 50 % of the engineers graduated from the traditional engineering education assessed the contents of the project work in their education as too little and the contents of the lecture courses with a fixed curriculum as too extensive.

The level of the courses in Aalborg were in some cases assessed to be too demanding, in other cases not demanding enough. In the traditional education with courses with a more fixed curriculum, the demands were assessed to be more appropriate for the students.

This can be explained by the constantly changing lectures in project-organized education. A price we have to pay if we always want the latest and most relevant knowledge in the lectures.

The other Danish university which produces graduate engineers is Technical University of Denmark..

Both universities are state-financed, they have the same grants for each student, and the same requirements for their graduates.

This gives us the possibility to compare the effiency between project-organized and traditional engineering eudcation.

A comparison between the two universities shows that project-organized education generates higher effiency with a lower dropout ratio and the main part of the students graduate at the prescribed time. In fact 80% of our students in engineering pass their examinations.

Parts of this chapter were presented in earlier versions at the Unesco Roundtable on Strategic Issues in Engineering Education (UNESCO/DIF) in Copenhagen 1992, the European Society for Engineering Educations seminar on Project-Organized Curricula in Engineering Education (SEFI/CDG) in Copenhagen 1993, the International Federation of Surveyors Commission 2 workshop on Educational Challenges (FIG) in Aalborg 1993, the International Conference on Teaching Science for Technology at tertiary Level (IVA) in Stockholm 1994 and the World Federation of Engineering Organizations 3rd World-Congress on Engineering Education (UNESCO/WFEO/ESE) in Cairo 1994.

Bibliography

Adolphsen, J.: Problemer i videnskab (problems in Science), Aalborg University Press 1985

Ahlgreen-Ussing, H./N. Fruensgaard: Metode i projektarbejde (Method in project work), Aalborg Unviersity Press 1990.

Andersen, J. Bach: aau-modellen på godt og ondt (The Aalborg University model for better or for worse). STUS-conference, Copenhagen 1990.

Arnbak, Jens/H. Boom/H. Langmaack/J. Keith Nelson: Evaluation of the Electrical Engineering Education at the Engineering College of Aarhus, Aalborg University and the Technical University of Denmark. Copenhagen 1992.

Bates, R.: A Set of Categories for the Analysis of Small Group Interaction. In American Sociological Review 1950.

Bates, R.: How People Interact in Conference. Scientific American 1955

.Beyer, K.: Project-organized University Studies in Science: Gender, Metacognition and the Quality of Learning. East and West European GASAT Conference, Eindhoven, 1992.

Blankertz, I.H.: Theorien und Modelle der Didaktik. München 1972.

Bond, David/Graham Feletti (eds.): The Challenge of Problem-based Learning. London 1991.

Botkin, J.W.: No Limits to Learning. Pergamon Press, Oxford , 1979

Boud, D./G. Feletti: The Challenge of Problem-based Learnbing. Kogan Page, Londong 1991

Bowler, T.D.: General Systems Thinking. Its Scope and Applicability. New York 1981.

Bull, P.: Body Movement and Interpersonal Communication. John Wiley & Sons 1983.

Christophersen/Coupe/Lenschow/Townson: Evaluation of Civil and Construction Engineering Education in Denmark. Centre for Quality Assurance and Evaluation of Higher Education in Denmark. Copenhagen, 1994

Collings/Ellswoorth: An experiment with a project curriculum. London/New York 1923.

Creese, R.: A Project centered Engineering Program. Engineering Education, November 1987.

Creese, R.: Project-based Manufacturing Engineering Program. Industrial Education, December 1987.

Dreyfus, H.: Why Studies of Human Capacities Modeled on Ideal Natural Science Can Never Achieve Their Goal. Boston Colloquium for the Philosophy of Science 1982.

Enemark, S.: Facing the Educational Challenges of the Future. FIG XX International Congress, Melbourne 1994.

Enemark, S.: Will the education be able to catch the challenge of the future? FIG XVIII International Congress, Toronto 1986.

Enemark, S. (ed.): Facing the Educational Callenges of the Future. FIG Symposium, Aalborg 1993.

Enemark, S./F. Kjersdam: Interaction between Engineering Education and Practice. The problem-oriented Approach. Second International Symposium for Engineering Deans and Industrial Leaders. UNESCO/FEANI, Paris 1991

Engström, Y.: Learning by expanding. Helsinki 1987.

Evalueringscentret: Censorrapport. Evaluering af de videregående bygningsingeniøruddannelser i Danmark. Bilag XIV (Report from external examinators in civil and construction engineering in Denmark) Copenhagen 1993.

Flyvbjerg, B.: Socrates Didn't Like the Case Method. Why should you? VI International Conference on Case Method Research and Case Method Application, Massachusetts 1989.

Frey, K.: Die Projekt-Metode. Weinheim/Basel, 1982.

de Graaff, E./P. Bouhuijr (eds): Implementation of problem-based learning in higher Education. Thesis, Amterdam 1993

Habermas, J.: Vorbereitende Bemerkungen zu einer Theorie der kommunikativen Kompetenz, Frankfurt am Main. In: Habermas, J./Luhmann, N.: Theorie der Gesellschaft oder Sozialtechnologie. Frankfurt am Main 1971.

Habermas, J.: Theorien des kommunikativen Handelns. Bände 1-2. Frankfurt am Main 1981.

Heitmann, G.: Zielsetzungen und Bedingungen projektorientierter Studiengänge. Studentische Politik 5, Bonn/Bad Godesberg 1970.

Hermanns, H./C. Thocz: Projectorientierung in Rahmen der integrierten Technik-Studiengänge an der gesamthochschule Kassel. Conference-Report, Bremen 1976.

Hiltz, S.R.: Evaluating The Virtual Classroom. (Revised and Updated). New Jersey 1986.

Horvat, M.: Interdisziplinäre Projektarbeit in der Ingenieur-weiterbildung. In: Bamme , A./H.J. Schellenberg (eds): Technologie-Entwicklung und Weiterbildung. Münch 1991.

Lames, W.K.: Development of Creative Problem Solving. The Technology Teacher, Virginia, 1990.

Jensen, S. A./M.F. Wagner: Ingeniørers arbejde og kvalikationer (The qualifications of engineering graduates). University of Aalborg, 1990.

Kerr, A. D./R. B. Pipes: Why we need Hands-On Engineering Education. Technological Review, Vol. 90, No. 7., 1987.

Kilpatride, W.H.: The Project-Method. Teachers College Record, Bd. XIX, Number 4, Colombia University 1919.

Kjersdam, F.: An Education to Catch the Challenge of the Future. Key lecture. SEFI, Copenhagen, 1993.

Kjersdam, F.: Evaluation of Project-Organized Engineering Education.European Journal of Engineering Education vol. 18, No. 4, 1993

Kjersdam, F.: Experience from Problem-based Project-Organized Engineering Education. FIG 1993.

Kjersdam, F.: Fysisk Planlægning og anvendt videnskab (Physical Planning and Applied Science). Chartered Surveyors Press, Copenhagen 1987.

Kjersdam, F.: High Quality Project-Organized Engineering Education - an Evaluation, 3rd World-Congress on Engineering Education WFEO/ESE/UNESCO, Cairo 1994.

Kjersdam, F.: Project-Organized Engineering Education. In: Jensen, H.P. and T. Hvidegaard: Unesco Roundtable on Strategie Issues in Engineering Education. UNESCO/DIF Copenhagen 1992.

Kjersdam, F.: Problem-oriented Higher Education for Engineering and Technology. In: International Symposium on Higher Engineering Education., Pergaman Press, Oxford 1990.

Kjersdam, F.: The Aalborg Experiment -Tomorrow's Engineering Education. European Journal of Engineering Education, Vol. 19, No. 3, 1994

Kjersdam, F.: Scientification through Problem-Orientation, Key Lecture. IVA/KTH International Conference, Stockholm 1994.

Kjersdam, F./S. Enemark: Who is to teach the teachers? - the problem is the question and the answer. FIG Symposium on University Education for Surveyors, Madrid 1988.

Kuhn, T.: The Structure of Scientific Revolutions. Chicago 1962.

Kümmel,M./E.Hede/S.Højbjerg/S.T.Lyngsø/S.Lehmann: Evaluering af elektroingeniøruddannelserne ved Aarhus Teknikum, Aalborg Universitetscenter og Danmarks Tekniske Højskole (evaluation of the Danish Electrical and Electronic's Engineering Educations). Copenhagen 1993.

Laursen, E./J. Broedslev Olsen: Projektarbejde i parksis - to undersøgelser (Project-organized studies in practice - two investigations). TNP-seriec 19, Aalborg Unviersity, 1992.

Lorentsen A./A. Kolmos (eds.): Quality by Theory and Practice of Higher Education. TNP-Series no. 6, AalborgU niversity , 1991.

Miller, A. H.: Student Assessment of Teaching in Higher Education. In: Higher Education, No.17, 1988.

Olsen, W.: Virksomhedslinien under lup (A Tracer Study of the programme in Industrial Management and Manufacturing Technology), Aalborg University 1992.

Owen, W. The Problem method. The Journal of Educational Methods, Yonkers 1921/22.

PLS Consult: Brugerundersøgelse. Dimittender. Evaluering af bygningsingeniøruddannelser i Danmark. Bilag XII (Survey among graduate civil and construction engineers in Denmark). Copenhagen 1993.

Polanyi, M.: Personal Knowledge. London 1962.

Polanyi, M.: The tacit Dimension. London 1967.

Pollard, A.: The Education and Training of Engineers for the 21st Century: A Forward Look. Followship of Engineering, London 1989.

Ramhøj, L.: The educational System at Aalborg University Centre. FIG XVI International Congress, Montreux 1981.

Rasmussen, Palle: De studerendes oplevelse af undervisningen ved Aalborg Universitetscenter (The students' evaluation of the project-oriented education at Aalborg Unviersity). Aalborg Universitetscenter 1991.

Schmithals, F./M. Cornwall: Projectstudium in den Naturwissenschaften. Bericht über ein Symposium. Bremen, 1976.

Schribner, S./M. Cole: The Psychology of Literacy. Cambridge 1981.

Searle, J. R.: Speech Acts. Cambridge 1969.

Slavin, R.: Learning to Cooperate, Cooperating in Learning. New York 1986.

Teaching and Case Method. Boston 1987.

Tippelt, R.: Projektstudium, München 1979.

Vinther, O.: Project-organized curricula in engineering education. SEFI-seminar, Copenhagen, 1993

In a real sense the establishment of Aalborg University in 1974 was an exciting experiment in higher education as important as, for instance, the Open University concept in the United Kingdom.

International Evaluation Panel.

The engineering programmes at Aalborg University are project-organized from the day the freshmen arrive until their graduation. In the programme Aalborg University has grasped the opportunity to meet the voiced need for education to be more closely aligned to an engineering problem-solving approach.

Comprehensive evaluation of the programmes in engineering and science has proved the concept to be an effective educational system wich produces readily adaptable graduates with strong qualities in the fields of management, problem-solving, co-operation and project work.

Finn Kjersdam M.Sc., PhD, Dr.Techn., HonFAB, is gratuated from The Royal Veterinary and Agricultural University, Copenhagen, Technical University of Denmark, Copenhagen, Nordic Institute of Advanced Urban and Regional Studies, Stockholm and Graduate School of Educational Management, Harvard University, Cambridge. At present he is Professor in Physical Planning and Dean of Engineering and Science at Aalborg University.

Stig Enemark, M.Sc., FRICS, is gratuated from The Royal Veterinary and Agricultural University, Copenhagen. Previously he was consultant chartered surveyor. At present he is Head of the Planning and Surveying Programmes and Reader in Land Management at Aalborg University. He is Chairman of the Professional Committee of the Danish Association of Chartered Surveyors and Chairman of FIG Commission for Professional Education.

Publication Information

Word Processing Ulla Christensen, Hanne Lauridsen and Vibeke Bo Jensen
Layout Finn Kjaersdam
Photographs Henning Bagger
Cover Ole Flyv and Finn Kjaersdam
ISBN 87-7307-480-2

Published by The Faculty of Technology and Science, Aalborg University and Aalborg University Press
Printed by Nordjysk Bogtryk, Aalborg
Distribution Aalborg University Press
Niels Jernes Vej
9220 Aalborg
DK-Denmark
Phone: +45 98152928

PROJECT EXAMPLE

BACHELOR THESIS (7th SEMESTER) IN ENGINEERING

THEME: Construction on the basis of demands in industry or society.

PROJECT: Test equipment for rubber materials.

Construction of equipment for the testing of mechanical characteristics of rubber. On the background of criteria of construction from industry, electronically operated equipment for mechanical testing of breakdown and compression of rubber with electronic computing of the results is developed. Construction, production and testing of the equipment, which met the criteria.

METHODS: Use of textbook, construction, design, computing and production.

EXTERNAL PARTNERS: Aalborg Rubber Industries Inc.

SUPERVISOR: Associate professor, PhD from Aalborg University.

CENSOR: Technical Manager and Chief Construction Engineer from private industry.

PROJECT EXAMPLE

MASTER THESIS (10th SEMESTER) IN ENGINEERING

THEME: Investigation of the potential for rational design techniques.

PROJECT: Rational design of a bicycle.

The objective of the design process was to design a frame with the best possible stiffness properties and the lowest possible weight. The stiffness properties are very important because the rider wants as much of his precious energy as possible converted into velocity rather than deformation of the frame.

The purpose of the first part of the project was to provide the basis for the construction of the frame, i.e. the correct loads and boundary conditions. Direct measuring of these loads under working conditions is very difficult. An identification approach was therefore adopted. The deformation of an aluminum frame was measured by strain gauges, and the result was compared with a numerical model. Identification techniques were then used to find a set for loads for the numerical model which would yield the same deformation as the physical model.

The next step of the rational design process consisted in evaluating a large number of differenct topologies, i.e. ways of assembling the frame from slender beams. Based on the best topology, an initial design was modelled numerically assuming the use of PVC foam coated with a shell of carbon and kevlar fibres, i.e. a sandwich construction. This initial design was then subjected to shape optimization with the purpose of improving the stiffness properties as much as possible.

The final frame was significantly different from the tradtional bicycle design. It has a weight of approximately 2 kg and stiffness properties which in some respect are more than 10 times better than a typical tube frame. It was physically built and tested with succes over a long period by a professional bicycle rider and at the Olympic games in Barcelona.

METHODS: Experiments, numerical/mechanical modelling, construction

EXTERNAL PARTNERS: Principia Bicycle Industry, Nr. Sundby

SUPERVISOR: Associate professor, PhD from Dept of Mechanical Engineering, Aalborg Unversity.

CENSOR: Associate professor from Technical University of Denmark and engineer from private industry.