The Aalborg Experiment.
University - Industry Interaction: A means for stimulating Engineering Excellence in technology and learning systems.

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Abstract: This article present what an engineering school at a university may do for stimulating the engineering excellence. Aalborg University experiment will be used as a case example with its unique use of problem-based education methods in connection with project and group-organised studies – to stimulate the professional learning process by a balancing of teaching/experience, theory/practice, disciplinarily/interdisciplinary and strengthen the link between research, education and practice. This presentation draws on the author's experience [1] with the never ended development and implementation of the Aalborg experiment since 1974.

Introduction: The Aalborg Experiment.

The University was established in 1974 as an experiment in higher education with 900 students from four different schools, now there are more than 13,000 students. The curriculum in Engineering as well in the natural science is project-organised from the day the freshman arrives until graduation.

There were special conditions for establish of AUC. It was situated in a Region of development with few traditions of higher Education. A new thing was also that more local Institutions of Education should be closed down and the programmes integrated on a new foundation in the University.

It should also be mentioned that the battle for placing a University in Aalborg was seen as a local national movement.

Especially the local national element had and still has a very important meaning for the Universities relations to the surrounding Society with the common goals and task: To strength the link between the academic and professional worlds together.

The four main goals of the project-based systems was and still are:

- Efficiency: To make the program requirement such that most students graduate on schedule without loosing professional competence:
- Quality: To increase student's self-confidence, flexibility, creativity, and communication skills as well as increasing their ability to work in teams.
- Flexibility: to solve interdisciplinary problems by improve faculty leadership abilities to direct students project teams so that project advisors become more coaches rather than lectures
- Innovation: to emphasise integrated problem solving, considering social, economical and political aspects as well as the technological aspects.

According to Danish culture and way of thinking:

- In the frame of problem based learning, project-based education.
- Driven by a democratic University administration.
- By government funding education.

From 1990 to 1994 The University of Twente [1,2] changed from classical to project-led education for the Mechanical engineering studies. No other institution had successfully made this changeover when they started in 1994 and this probably remains true in 2003, although some other universities have started developing similar initiatives on a scale which matches their needs and perceptions.

Major Differences in Education Systems – Is it Time for the US to Change [3]?

In the following I will very short point some important element of the concept, give some cases, point out some few experience from the university - industry interaction and then go to summarising and conclusion. For more detailed information about this, I can strongly recommend [1], [2], [3], [5].

The Danish Industry.

Denmark is a society with dense underbrush of small and medium size enterprises.

In figure 1 only those branches are counted which normally purchase the graduates from the higher education. Whtrad. is all types of wholesale-trade. Mo+Bs. is money and business included banking but excluded retail-sale. Serv. includes all types of private service, consultative, juridical or auditing. The columns show that even in the branch of manufacturing (Manuf) the small and medium size enterprises hold a clear majority.

The Danish home market is by nature small, but it is open. It means the possibility to live and compete in the market is closely connected to the ability to meet the actual demands of the customers and to do those before the bigger enterprises have established themselves with large-scale production. We often use the expression 'Niche-production' for that type of production is typically carried out in the small and medium sized manufacturing companies.

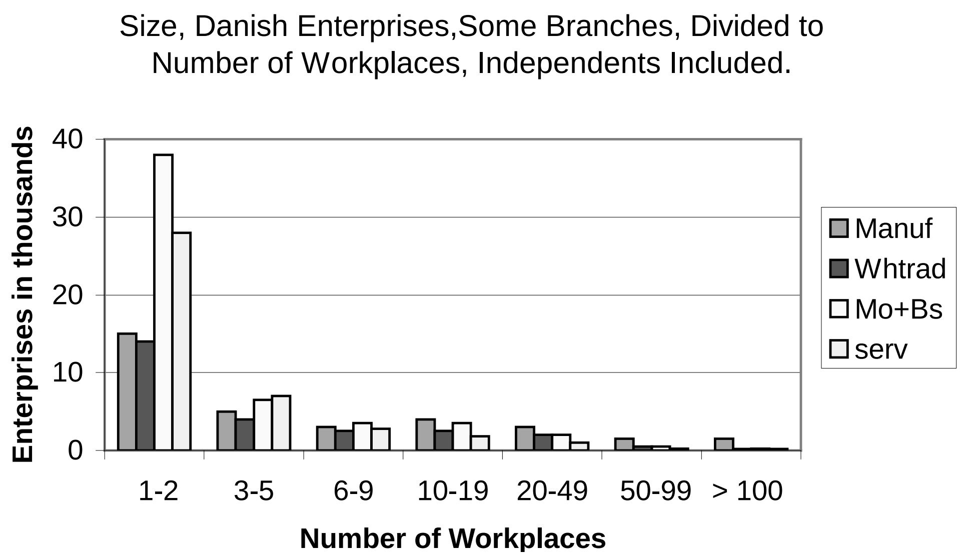

Figure 1. Density of small and medium sized enterprises. Manufacturing, wholesale-trade [5].

The small and medium size companies have a common need for a generally higher education level of their personnel, and in general they have a bigger ratio of high-educated persons than the big companies [5].

An immediate solution could be to increase the number of study-lines according to the development. Questionnaire, however, among some of the most trend setting Danish enterprises show that they preferred basically well prepared graduates more then some with less basic knowledge and more specialisation. Further they ask for more ability to change.

Therefore the assessment's (demands) from the industry to teach young people, students to become useful members for industry is, that the students are able to:

- Identify, analyse, formulate, process and solve complex problems.
- Assess technology in a social context in order to solve social problems, fulfil social needs and not create unwanted side effects.
- Acquire and apply new theoretical and practical knowledge as well as up-date old knowledge
- Be flexible, co-operative and communicative.

The Aalborg concept

The Aalborg University model of project based learning is comprised of the concepts of problem based learning and project work including:

- Problem orientation
- Experience-based learning
- Interdisciplinary
- Gradual specialisation
- Project work in groups

To emphasise learning instead of teaching is the main idea behind both project work and problem based learning. Learning is the active process of investigation and creation based on the learner's interest, curiosity and experience and should result in expanded insight, knowledge skills.

As with more traditional educational systems some of the important questions are:

- How to motivate the students?
- How to determine the elements in a curriculum?
- How to balance the different elements in the curriculum?

Some of the important questions related to the role of the teachers are

- How can we make the teacher-student contacts most efficient?
- How does the teacher's teaching task comply with the research task?
- How can we make connection between different teaching subjects?

The questions listed above are all open-ended.

The pedagogical concept of the Aalborg model.

The curriculum in Engineering [4] as well in the natural science is project-organised from the day the freshman arrives until graduation. In the problem-oriented project work the students deal with some degree of unsolved problems within in science and profession in a dynamic interplay between development, applied and pure science figure 2.

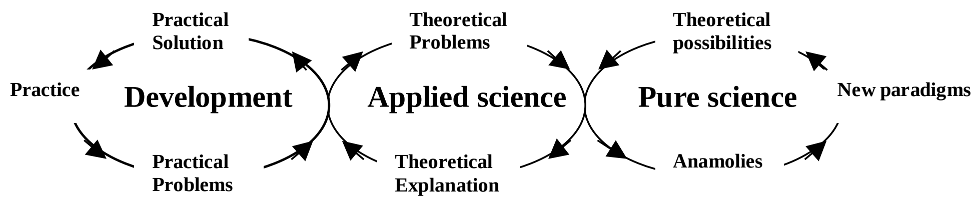

Figure 2. The dynamic interplay between development, Applied and Pure Science [1]

Authors [5] have described the project work as study form in different diagrams and pictures. Figure 3 gives an issue specified for the present lecture. The figure focuses upon the difficulties to maintain for the students and to be aware of for the teachers as supervisors if project work shall succeed. The area of the boxes in this diagram does not refer to the time volume of each task but to the mental change and effort needed to fulfil a project. The project itself from the very beginning is often only soft and unclear defined.

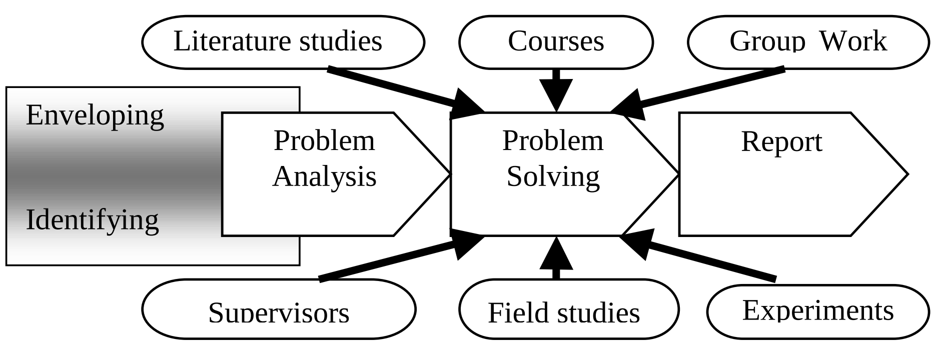

Figure 3. Project Work as a Study Form [4, 5l]

A big and demanding part of the work, therefore, is to envelope, identify and analyse that part of the total whole which is to be solved through the project. This enveloping, identifying and analysing must go on in an iterative process with scientific methods available and usable for the actual topic. It is like walking in a staircase. Seen from above it can look like walking in circles, but seen from the side, the students' position, one can recognise a constantly increasing level.

The supervisors of project-organised education need to be aware of that and not press the project group too hard in the first part of the project period. If that phenomenon is not taken in consideration, the students will tend to fall back to the 'Do as Learned Method' and find only conservative solutions.

The project-work is supported by relevant lectures and prepares the students by a great deal of self-training, supervision and often interaction with Companies.

The demand from the project work is [5]:

- Ability to perceive a complex situation in a systematic way. And from those observations identify and envelope the main elements.
- Ability to identify possibilities and limitations of methods usable to maintain those elements together with their interactions.
- Abilities to handle such methods in a scientific way.
- Ability to look for additional knowledge also outside subjects given in courses.
- Ability to use such knowledge, eventual with the help from the supervisor.
- Ability to include calculations or evaluations of consequences. And by that find the optimum among the potential solutions.

Structure and study curriculum.

The main element of the pedagogical concept is study plans, which for each semester describes courses and prescribes a theme for each term. Inside the semester theme each supervisor together with a student group can choose a project. The project time is calculated theoretically to cover half of each semester except in the final one in which the project covers the whole term. In praxis the students use more time for their projects. The five-year's education for a master degree is disposed in 4 phases for gradual individual choice of specialisation. Table 1 shows the phases and the semester themes with examples of semester courses.

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Most of the projects are carried out in groups of students, which allows for practising inter-personal communication skills. Unfortunately, resource constraints at our university often lead to relative large groups of students.

The use of the problem-based learning approach especially in the engineering education suggest that co-operation with private as well as public enterprises should play an important role for strengthen the link between the academic and professional worlds. Over the years personal and industrial relations have led to a number of different modes of co-operation of mutual benefit in other areas of M.Sc. programs.

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

The second phase the common ground the themes provide for teaching the necessary disciplines though courses and for training the professional functions through the project work. Therefore this phase is characterised by design.

Phases	Semester	Theme	Courses
Final	10	Master Thesis	None or free choice.
	9	Technology development/ Master Thesis	Outsourcing, Investment and decision theory, Laws/rules for companies, Strategy planning
Specialisation	8	Design/planning and manufacturing	Product data and product modelling, Generation of data for manufacturing. Methods of optimising, Systems identification, Elementary methods, Marketing, Advanced materials and processes, Development of information systems.
	7	Carry through of manufacturing	State-space modelling, Systems theory, Methods of elements, Production control, Structural programming, Assembly methodology, Simulation, Constitutive modelling
	6	Manufacturing processes	Dynamics, Partial differential, equations, Theory of plasticity, Manufacturing processes, Experimental methods for Engineers, Welded designs, Finite element, Modelling of processes, Metrology.
Common ground	5	Production Preparation	Production planning, Human factors, Physics, Organisation theory, Quality Control, Probability Theory
	4	Production process Realisation	Mathematics, Mechanics, Plastic forming, Control systems, Metal cutting, Foundry
	3	Engineering design	Mathematics, geometry, Materials, Mechanics, Strength analysis, Engineering design.
Basis	1 +2	Engineering problems: Model and reality, Models reality	Mathematics, Physics, Computer Science, Technology and society etc.

Table 1.The speciality in Industrial Technology offer a professional competence in solving complex manufacturing problems in connection with development, design, planning, shop floor control for implementing industrial manufacturing.

The third phase - the specialisation - the students within broad limits can choose their themes for obtaining a professional profile and choose their problems within the themes for obtaining special knowledge e.g. Industrial Technology. The themes have a more scientific research approach and will provide for teaching the necessary theories and knowledge's within the specific professional areas, and for training the methodological skills of problem analysis and applications as shown.

The fourth phase, the 9th and 10th semester is only for preparing a long master's thesis that is written as project work dealing with a problem chosen by the students groups themselves. They can also choose to use 9th semester for a free studies, often abroad and then make a short 10th semester masters thesis.

University-Industry Interaction

The University-Industry interactions have great potential for mutual benefits when keeping in mind that there are two different worlds, the life in industrial enterprise and in academia. The benefit of the problem-solving approach contributes to identify university core competence and thereby raise suggestion for new problems to solve. Often the teachers not only have the task delivering engineers fit for the industry. Through the industrial related projects they have to be prepared for tasks as educate industry directly by advice, training and problem solving.

The use of the problem-based learning approach especially in the engineering education suggest that co-operation with industry should play an important role for strengthen the link between the academic and professional worlds. Over the years personal and industrial relations have led to a number of different modes of co-operation of mutual benefit.

Following the four stages of the Kolb [6] or Cowan [7] learning circle, the engineering problem solution let the students to be involved in e.g.: 1) analysis and diagnosis of industrial issues, 2) development/design of solutions - holistic as detail, 3) planning/implementation and control of solutions 4) a dynamic learning process as benefit for innovation, research, methodology, tools and new knowledge,

which naturally involves special attention to reflection and be aware of the potential possibilities and resources in connecting to human, social and technical dimensions in a necessary interplay between crossover, development, decision and carry out processes.

Most of the projects are carried out in groups of students, which allows for practising inter-personal communication skills. Unfortunately, resource constraints at our university often lead to relative large groups of students.

By establishing good relations to the purchases of graduates and research results a valuable and inspiring, actual feed back is obtained. Interesting student's projects are carried out and often continued in real and actual research projects and programs. The two 9-10 semester project described by the author [1] have inspired to more ongoing Ph.D. projects, which in the moment is carried out more are under planning.

A great spectrum of interaction.

As PML [5] quote:" The risk of a close co-operation between a university and the enterprises is that the studies and student groups can appear to be something like free consultative partners and with short term's solutions only. The real risk of that would be a lower scientific but more pragmatic level of the studies.

In general the enterprises have a considerably shorter strategic perspective than that necessary at a university or other higher education's. Many small and medium size enterprises have a high degree of product development and product adaptation. Here the expression ‘Product’ is used in very broad meaning which includes also service-products.

However, by nature such small and medium size enterprises have only little tradition in research work, if any at all. Even rather big enterprises are looking for solutions ready to cook, or at least solutions developed from already existing results of basic research.

That means, if a university leans against enterprise projects alone, the basic research together with the students training in fundamental scientific methods will come to starve.”

Examples of interaction

- Several groups of students work in parallel on an industrial, typical 5. Semester projects
    - Very small enterprise: An inventor- an experienced yachtsman- has produced a lifeline but has not succeeded in turning into a sales success. 22 groups reengineered the product. It turned out that the groups made 22 different projects in terms of both product and production improvement. Furthermore, the product was afterwards commercialised based on suggestions from some of the projects.
- A group of 4 – 7 students engages in issues of an industrial enterprise, typical 6,7 and 8 semester projects. Cases from Industrial Technology.
    - Larger enterprise. 6.sem. The starting point is a manufacturing and quality point of view in connection with two automated TIG welding processes within an inspired co-operation with a larger industrial enterprise. There were carried out a comprehensive scientific experimental research in the laboratory with the 14 critical parameters accounting for receiving a profound theoretical examination. An advanced mathematical model was developed as well developing and programming of a neural network.
    - Small enterprise. 7.sem. After a profound analyse of the companies chain of order and manufacturing the group choose to design a data collection system accounting for illustration of and visualisation of machine data. The physical system was specified, designed and implemented. There was elaborated an data collection program in HP VEE to visualise the real time status and possibilities of control for the actual production with the purpose to increase the quality, productivity and efficiency. With the use of JAVA there were carried out a data treatment program for visualisation and collection data from files. The program was developed in modules for more functions in a way so it in the future could be extended.
    - Small Enterprise. 8.sem A Danish manufacturer of yarn and net for the fishing industry wants with support of advanced numerical simulation to obtain a better comprehension for the physical characteristics for their products and manufacturing properties with special reference to strengthen of the position and competition. Through out the project there were focus on finite element modelling of trawl as well in conventional as in new advanced high strength materials. Likewise there were focus on development and use of computer assistant simulation tools for design and manufacturing to obtain an efficient order treatment and assessment of proposal for further for development and designs.

- A Master thesis project (one to three students) can be a 9 semester preliminary project and a more focused on 10. Semester.
    - Small/medium enterprise. 9.sem/10sem. Integrated product development, In co-operation with a smaller company the focus was development, design and order treatment of systems (mechatronic) for palletising. The interim project (concept development) was carried out in Sydney University, Australian. The students also carried out courses in electronic, programming and methods of optimisation. In 10th sem. the concepts undergo a further development and the design process took over together with the use and development of methods and computer added tools. As well focus was on development and design of computer control systems, which could be adapted to the customers planning a control systems for manufacturing.
- An industrial PhD. project engages in a broad development project in an industrial enterprise.
    - Medium enterprise. Going project: How can industrial companies relate to, introduce and absorb new technology, with the objective to strengthen and improve the company's ability to innovate and thereby its business.
- A post-experience student following a part-time Masters program initiates a development process in his own company.
    - Larger/medium/small and smaller enterprises.
- Research and development program.
    - Industrial case studies.
    - Medium/Larger enterprise. Going program: Centre for Industrial Production. Mission: Through basic and applied research to develop new knowledge and innovative solutions of value for Danish Industry [8].
    - Nationals
    - EU
    - --

In short statement we can quote

The curriculum in Engineering as well in the natural science is project-organised from the day the freshman arrives until graduation.

The subject works with project even how different the task maybe - has some common characteristics [9]:

- are complex – in a form of difficult clear in system coherent and interplay between people and technique,
- have characteristic of development – in a form of finding new solutions and try new ways,
- demands a interdisciplinary effort, where people with different professional knowledge has to be involved in the solution of the project,
- demands a interorganised effort from different department and instances in a form of resource contribution, acceptance etc.,
- subject for a multiorganised interest , i. e. that more departments, institutions groups of employees have interest in the project and the solution,

- has a considerable amount of human resource, expenses and economic results,
- guide to a result of essential extent and importance – in the light of relations to ex amount of people, who will be affected, the result's functionality (lifetime) and economic influence,

which naturally involves special attention to reflection and be aware of the potential possibilities and resources in connecting to human, social and technical dimensions in a necessary interplay between crossover, development, decision and carry out processes.

By establishing good relations to the purchases of graduates and research results a valuable and inspiring, actual feed back is obtained. Interesting students projects are carried out and often continued in real and actual research projects as a means for stimulating engineering excellence of technology and the learning systems in the University and the Enterprise.

The graduates achieve great experience in interdisciplinary teamwork and they will normally posses 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.

Two worlds are to co-operate.

- Different goals, criteria and success and reward systems.
- Different time horizons.
- But potential synergy and benefit by using Industry as a laboratories for teaching and research.

Benefits in the industrial, education and research areas.

- Competence development rather than a project.
- Innovative solutions.
- Attention to development issues.
- New tools and methods.
- Updating of knowledge.
- New point of views.
- Cross-functional discussions.
- They can promote themselves.

A continuous act of balancing.

- Focus, time and effort- two different goals?
- Students are often to eager to engage in company problems.
- A spectrum of solutions – from repair to radical innovations.

New role of the teachers.

- Good lectures will always be appreciated.
- From lecturer to coach.
- Emphasis on facilitation of group projects.
- You are rewarded for research.

Very crucial issues to be solved - if possible.

Can industrial co-operation/research be acknowledged?

- Researchers are under press to focus.

- How to increase the academic esteem for multiperspective research addressing complex industrial issues
- Avoid to be bind of the agreement of confidentiality so that scientific Article's and other publication's are impossible,

Summery and conclusions.

At Aalborg University very good experience is obtained by using the problem-orientated and project-organised study method in a project co-operation with enterprises, private as well as civil enterprises. The concept contents some difficulties and some risks. They are, however, to be maintained without attacking the academic independence.

By establishing good relations to the purchases of graduates and research results a valuable and inspiring, actual feed back is obtained. Interesting student projects are carried out and often continued in real and actual research projects as a means for stimulating engineering excellence of technology and the learning systems.

The University –Industry relationship plays an important role offering potential opportunities and benefits for both parties. However, attention should be given to ensure transparency in objectives in a continuous strive to balance scope, conflicting interests and effort.

I am convinced that the problem-based learning methods can contribute to stimulating and strengthen engineering excellence in the academic and professional world, but we will never find "one best way" mainly of culture reasons, Creese [3], Boer [10] and Hofstede [11].

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