

Retaining electronic engineering students by project- and team-work from the first semester

Anna Friesel

Professor, Head of Section
Copenhagen University College of Engineering
Ballerup, Denmark
afr@ihk.dk

Abstract— This paper describes the experience of teaching the basics of engineering: calculus and the basics of physics as part of a project- and team-work initiative in the department of Electronics and Information Technology, at Copenhagen University College of Engineering (CUCE) in Denmark. All the basic courses in the first and second semester have been taught as part of projects and involve teamwork. Modern engineering students are difficult to motivate in order to learn pure theoretical issues such as solving differential equations. Especially when we talk about undergraduate engineering students, who do not expect to continue their education higher than a Bachelor of Science in Engineering. At the same time, and for the same reason, the fail rate in mathematics is very high during the first two semesters. This was the reason we decided to change the structure of our education and incorporate the theory with practical projects. This paper describes some of the projects. The projects are the motivating factors to learn mathematics. The examination results show improved learning potential, when using this method of engineering education. The students' evaluations show a very positive effect on their experience with this "practical" way of learning theory. At the same time, the evaluation results have shown higher pass rates and higher grading.

Keywords - Motivation, Project based learning, Teamwork

I. INTRODUCTION

The research confirms improvement of the learning outcomes in education when the theory is combined with practical training or projects [3,5,8,10,13,14]. Usually the project-based courses are introduced after the students have passed the first 2-3 semesters of the engineering basics, like calculus, physics and computer programming. Students who wish to work professionally with electronics, computers and telecommunication, and who do not wish to continue for Master Degree, are not motivated to use 2-3 semesters for pure theoretical studies [11,12]. These students usually have high fail rate in mathematics and physics in the first 1-2 semesters and, as a result, many of them stop. On the other hand we must introduce the theory in order to understand and work with a number of complex engineering disciplines. Considering the students' wish to work with real engineering projects and the requirements to master the basics of mathematics and physics, the message is clear: the students will be more likely "to stick with derivatives and integrals" [6] if we can offer them some

evidence of how necessary these tools are in order to find solutions for engineering problems[1,2]. If we use this strategy from the first semester the students will experience that they already make progress towards completing engineering work/projects and the positive influence will be shown in an increased pass rate. There are different possibilities to include experimental work together with theory in engineering [7,9,17] like:

1. Using simulations programs involving graphics and animations in order to visualize mathematics and physics.
2. Mixing the theory classes with laboratory exercises.
3. Study-tours to industrial companies.
4. Inviting guests from industry for lectures.
5. Make students to work with engineering projects in teams.

In particular the engineering students benefit from new technologies [4], as they actively use both Internet and simulation programs [20,21]. Teaching theoretical mathematics today is a very challenging task, even more so when we talk about undergraduate, practical oriented engineering students. The engineering students' expectations for their study program are more practical and experimental activities, then the calculations of the theoretical problems with pen and paper. Many universities and engineering colleges have the opinion that pedagogical activities must actively involve the students in order to motivate them to learn basics of mathematics and physics [17]. Problem-based learning and working with projects has already been implemented in engineering educations in many different universities [1,3,9]. This paper presents how we implemented the calculus and the basics of physics in the curriculum for undergraduates, as a part of projects in the first two semesters.

II. STUDY STRUCTURE

Some years ago, we went through the process to renew the educational study structure in our department and we decided to change the study structure in CUCE towards more projects and teamwork. Similar changes were made for all semesters in our programs, involving the basic courses in mathematics and physics. Example of our program in electronics and information technology is shown in Table 1.

TABLE I. EIT- STUDY PROGRAMME

ECTS	1. sem	2. sem	3. sem	
2.5	Object Oriented Prog. 1	Object Oriented Prog. 2	Electromagnetism	
2.5				
2.5	Project 1	Project 1		
2.5				
2.5	Mat1 (DSM1)	Mat2 DSM2	Mat1 (DSM1)	
2.5				
2.5	Digital Electronics 1 Project 2	Digital Electronics 2 Project 2	Projects	
2.5				
2.5				
ECTS	4. sem	5. sem	6. sem	7. sem
2.5	DSM4	Practical Training	Elective	Bachelor-project
2.5				
2.5	Elective			
2.5	Elective			
2.5	Control Theory			
2.5				
2.5	Robot-Project			
2.5		Elective		
2.5				

Project- based learning requires a high degree of concentration on particular topics, and in order to support this educational method we also changed the weekly time schedule. Students have only two modules/topics during one day, one from 8:30-12 and one from 12:30-16:00. Each module includes four lectures of approximately 45 minutes and some necessary breaks in between. The example of weekly schedule is shown in Figure 1. One module of tuition is usually related to a course of 5 ECTS credits, and one module of teacher tuition requires on average 4 hours of self-study for the student.

Mon	Tue	Wed	Thu	Fri
08:30-12:00	5 ECTS Credits			
12:40-16:00				

Figure 1. Weekly Schedule

III. FIRST-, SECOND- AND THIRD-SEMESTER MATHEMATICAL COURSES

The first semester mathematics course has the following content:

- Linear algebra, basics.
- Signals and systems.
- Complex numbers
- Number systems and number representation.

- Polynomials.
- Infinite series.
- Fourier series in continuous time.
- Differential equations, in project context
- MATLAB

The course has a value of 10 ECTS course with two modules per week. In connection with this course the students work in teams on projects connected to all the courses they have in the first semester. These projects give an additional 5 ECTS and are a mix of mathematics, digital signal processing, programming and digital hardware. Examples of first semester projects are:

- Development and implementation of the algorithm for Gauss elimination
- Development, programming and hardware implementation of the algorithm for an elevator's movement
- Apply differential equations in the description of a simple physical system and make a MATLAB simulation

During the semester, the students develop the following skills:

- how to work in teams,
- how to make a presentation for tutors and other teams on seminars,
- define and describe the fundamental problems and concepts introduced in the course – using proper mathematical notation,
- define and describe the fundamental methods for solution introduced in the course – using proper mathematical notation,
- define and describe a feasible algorithm based on a mathematical method for solution - allowing a subsequent implementation in MATLAB.

The second semester course in mathematics is a combination of Digital Signal Processing and discrete mathematics (DSM2). The content of this course is:

- discrete-time linear systems in the time-, frequency- and z-domains,
- design and implementation of digital filters on a digital signal processor including A/D and D/A converters,
- MATLAB used as simulation tool.

The projects connected to this course are concentrated on the following:

- set up specifications for the amplitude response of FIR and IIR filters,
- apply the design tools of MATLAB to calculate the filter coefficients,
- implement and test by measurements digital filters using a DSP evaluation kit.

The non-technical skills learned during the second semester's courses and projects are:

- how to work out written reports in connection to the course assignments and projects,
- how to collect information and acquire new information and knowledge,

- how to communicate technical problems in writing and speech,
- how to cooperate in teams.

The third semester courses combine mathematics, physics, and electromagnetism and circuit theory. Mathematical modeling is used as a tool to describe mechanics, electromagnetism and circuit theory involving differential equations.

The projects on third semester are more advanced, like:

- Specification, analysis and design of electronic scale. DC-project, (figure 2).
- Design of the metal detector, AC-project and filter design, (figure 3).
- Mathematical Modeling of the electronic scale, comparison between measurements and simulations (figure 4).

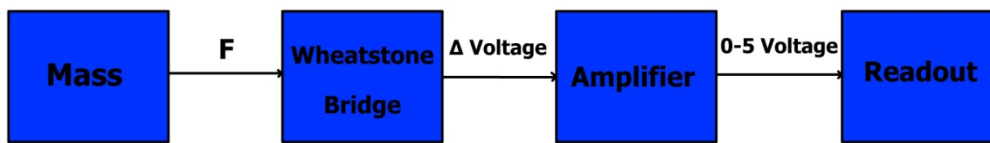


Figure 2. Block diagram of Electronic Scale, DC-project.

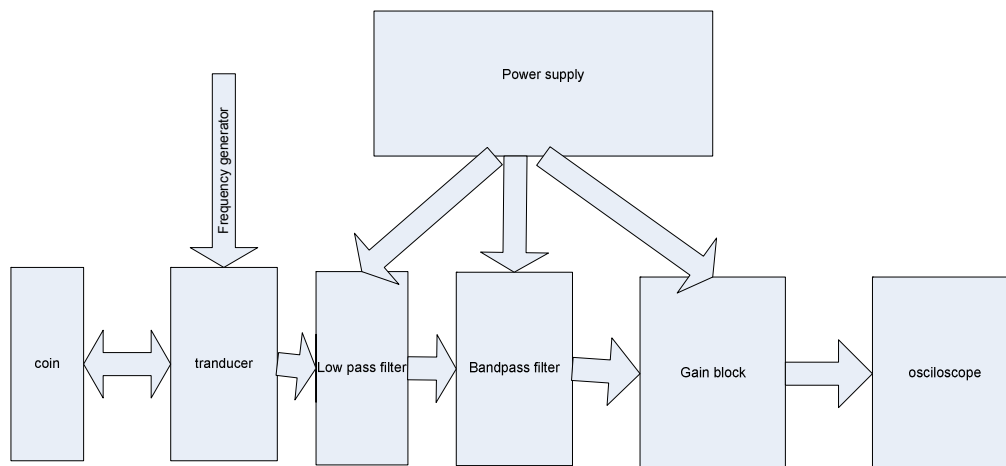


Figure 3. Block diagram of the metal Detector, AC-project

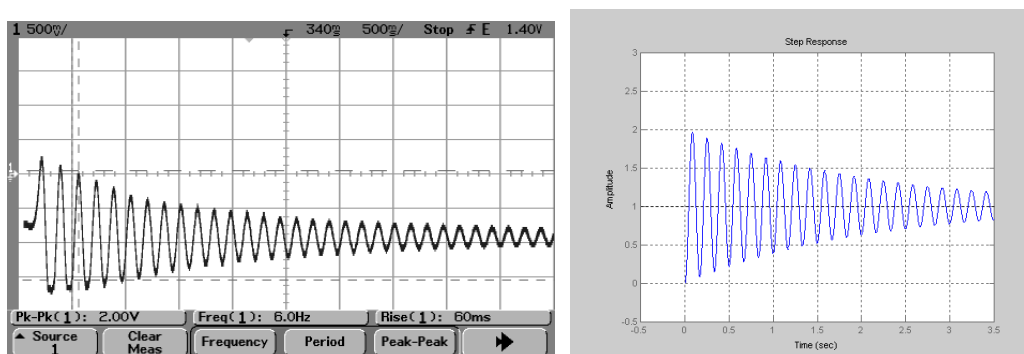


Figure 4. Electronic scale and simulation

The documentation of the practical design and experiments are described in the reports and give the basis for the evaluations of the projects on each semester. This is an advanced process of learning, where the students have the responsibility for combining the theory and practical electronics design [8, 9, 15]. The motivation to learn basics of mathematics and physics is improved, compared with traditional classical educational methods, where the students learn all the theory in pure theoretical courses during the first semesters of their education.

IV. THE EXAMINATION

The examination process in Denmark involves by law an external examiner certified by the Ministry of Education, for all examinations at the university level. For engineering departments the external examiner is very often a company manager. The role of external examiner, among other things, is to keep the engineering curriculum up to date. The external examiner has a great opportunity to discuss the contents of the engineering courses including: pedagogical methods, experimental work, and projects when he or she participates in the examination. The external examiner has to report his/her conclusions about the examination level, and the level of education to the chairman of the external examiners, who is approved by the Ministry of Education. This procedure gives the industry an influence on the engineering education in Denmark. The industry can easily have influence to change the engineering departments' curriculum according to the needs of the industry. On the other hand the students meet their future managers, and get the knowledge of the requirements in industrial companies at the same time.

The examination, for project related courses, is both group- and individual- examination, but the marking is always individual. The evaluation is based on a general impression of the level achieved by the student relative to the objective of the project based course. The examiners, teachers, and the external examiner have read the students' three reports in advance. The students present the results of their work, both as the oral presentation and as a practical demonstration of the hardware. The questioning, which is a part of individual examination, begins after their group presentations. After questioning, the students leave the examination room and the examiners discuss their presentations, as a group and as individuals. The marks are given individually, and the students, one by one are invited back into the examination room for the explanation of their marking. After the examination the students can evaluate the course anonymously on the Campusnet [18] (Figure 5). Campusnet is an intranet portal for students, teachers and university administration. It is also Course Management System, where all students can add and drop classes, view and print their schedule, manage their account, request transcripts, forward email, view grades, and more. Instructors and teachers can view their schedule, and view student information.

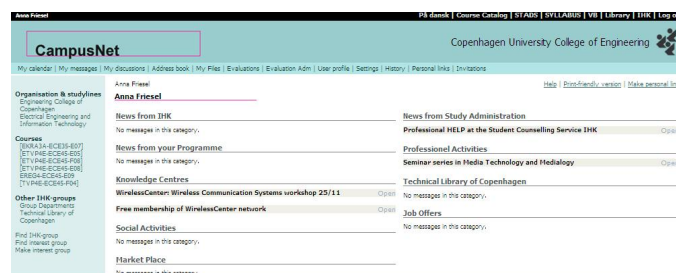


Figure 5. CampusNet at CUCE

V. STUDENTS' EVALUATIONS

Students make evaluation of their courses twice during the semester, in the middle of the semester and after the examination. The final evaluation, after the examination, is made on CampusNet and the results of this evaluation are available to the students participating in the course, the teachers and the head of the department. The evaluations include three parts: course evaluation, teacher's evaluation and general comments. The questionnaire is shown in Table II.

TABLE II. COURSE EVALUATION QUESTIONNAIRE

Course evaluation	
1. Target fulfillment:	
To what degree has your learning measured up to the course description?	
<ul style="list-style-type: none"> To a very high degree To a great degree To a suitable degree To a low degree To a very low degree 	
2. Your own performance	
2.1 How much time do you estimate you have spent on the course compared with the expected time?	
<ul style="list-style-type: none"> < 50% 50% - 70% 70% - 100% 100% - 130% > 130% 	
3. The relevance of the course:	
To what degree do you consider the course relevant for your education?	
<ul style="list-style-type: none"> To a very high degree To a great degree To a suitable degree To a low degree To a very low degree 	
4. The academic level of the course:	
To what degree has the course challenged your academic abilities/competences?	
<ul style="list-style-type: none"> To a very high degree To a great degree To a suitable degree 	

To a low degree To a very low degree
5. The study material:
To what degree has the study material supported your learning?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
6. The teaching method:
To what degree has the teaching method supported your learning?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
7. The test/examination method:
7.1 To what degree do you find that the examination method matched the method of teaching?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
7.1 To what degree has your learning measured up to the course description?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
7.2 To what degree do you find that the test/examination method is suitable for testing whether the objective of the course has been fulfilled?
To a very high degree To a great degree To a suitable degree To a low degree To a very low degree

1.2 To what degree do you find the academic instruction you received, in connection with the preparation of assignments, to be sufficient? <ul style="list-style-type: none">To a very high degreeTo a great degreeTo a suitable degreeTo a low degreeTo a very low degree
2 The teacher's instruction regarding teamwork, study methods etc.:
2.1 How do you evaluate the quality of the process instruction you received in connection with the preparation of assignments? <ul style="list-style-type: none">Very goodGoodSatisfactoryPoorVery poor
2.2 To what degree do you find the process instruction you received, in connection with the preparation of assignments, to be sufficient? <ul style="list-style-type: none">To a very high degreeTo a great degreeTo a suitable degreeTo a low degreeTo a very low degree
3 The teacher's feedback on student work with assignments etc.:
3.1 How do you evaluate the quality of the feedback you received on questions, work with assignments etc.? <ul style="list-style-type: none">Very goodGoodSatisfactoryPoorVery poor
3.2 To what degree do you find the feedback on questions, work with assignments etc. to be sufficient? <ul style="list-style-type: none">To a very high degreeTo a great degreeTo a suitable degreeTo a low degreeTo a very low degree
4 The teacher's presentation of the subject matter and ability to put into perspective:
4.1 To what degree did the teacher's presentation, summarizing and putting the new subject matter into perspective support your learning? <ul style="list-style-type: none">To a very high degreeTo a great degreeTo a suitable degreeTo a low degreeTo a very low degree

Teacher's evaluation
1 The teacher's instruction in connection with the preparation of assignments:
1.1 How do you evaluate the quality of the academic instruction you received in connection with the preparation of assignments? <ul style="list-style-type: none">Very goodGoodSatisfactoryPoorVery poor

<p>4.2 To what degree do you find the feedback on questions, work with assignments etc. to be sufficient?</p> <ul style="list-style-type: none"> To a very high degree To a great degree To a suitable degree To a low degree To a very low degree
General comments
1.1 What was good or worked well in the course?
1.2 What was bad or worked badly in the course?
1.3 What are your suggestions for improvements?

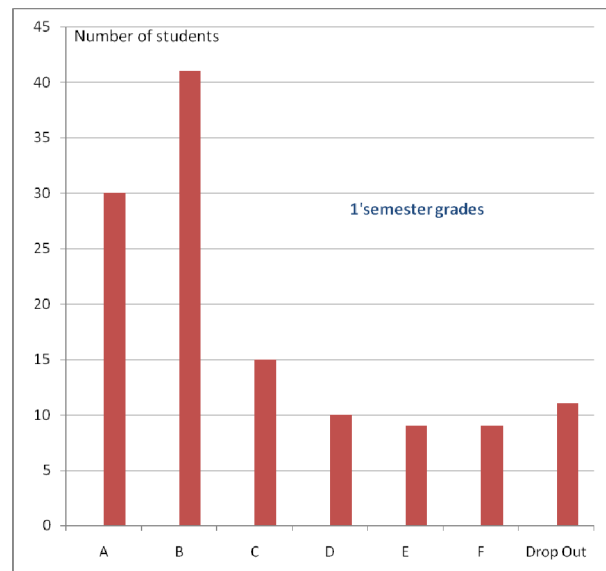


Figure 6. The examination results

Table III shows the statistics of the first semester's evaluations. The results of this evaluation were as follows:

- 68% of the students (who answered the questionnaire) were either very satisfied or satisfied.
- 72% of the students felt that the teaching method supported their learning very well.
- 84% of the students find that the test/examination method matched the method of teaching.

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TABLE III. THE STATISTICS OF THE FIRST SEMESTER'S EVALUATIONS

1.Semester	Questionnaire	Total	Percent
ECD11	21	32	66%
ITD12	19	26	73%
ECD13	13	18	72%
ECE15	18	25	72%
ECE16	7	24	29%

VI. CONCLUSIONS

After several semesters of completed Project- and Team-Based basics courses in department of Electronics and Information Technology, we can make the conclusion, that the main objectives have been achieved. The students have got a better understanding of the mathematical tools in engineering. We have also observed much better understanding of more advanced engineering physics during the fourth semester of their education. The students' own evaluations show an increased motivation to learn mathematics and physics in this practical approach to the theory, especially for the students with previous practical experience. The examination results are shown in graph on Figure 6, it is clear that we have highly improved the pass rate for first and second semester students, and the overall dropout due to theoretical mathematics is much lower. The level of drop out after first and second semester is now below 20%.

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