Mathematical Modelling in Electronics and Medialogy – Sharing Experiences for Better Results

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Abstract

The progress of science and technology emphasizes the connection between different domains and modern education is establishing interdisciplinary links between the subjects. Engineering education must therefore change its focus from purely scientific and technological programs, to be a mix of different disciplines, gaining access to scientific and technological innovations through interdisciplinary projects, modeling, simulations and practical model building. Considering young people's desire to work on real-life projects and the requirements to master the basics of mathematics and physics, the conclusion is quite clear: we have to offer them some evidence of how necessary the mathematics is in order to solve problems in connection to real engineering projects. One of the best strategies is to introduce students to project based education in mathematics from the first semester, in order to increase the pass rate and decrease the drop-out rate. There are different possibilities to involve students actively in the learning process like using simulations programs involving graphics and animations, mixing the theory classes with practical exercises, excursions to companies or inviting guests from industry for lectures. Project Based Leaning (PBL) combines all the named issues. The additional merits of this method are increased motivation and experience in interdisciplinary problems and solutions. Sharing and exchanging experiences between our two universities was beneficial for learning outcomes of our students. Working with practical engineering projects make them better motivated to acquire mathematical tools needed to work with complex engineering problems. We describe some of the courses and projects at both educational institutions, and our cooperation across out two universities. We conclude by analyzing the results achieved by students compared to purely theoretical courses.

1. Introduction

The engineering education is by its nature based on knowledge of mathematics and mathematical reasoning. The dynamics of mathematical reasoning, and in general every kind of scientific reasoning, include components like mathematical notion, formal, axiomatically organized way of thinking, and at the same time one need to involve logic and abstract reasoning. This is why the mathematical education in engineering, and especially at the bachelor level, has given the conflict of interests. On one hand, many curricula and text-book writers have tended to "correct mathematical" – an explicit and complete proof method – in order to explain mathematical context. Then this "correct mathematical" approach make it boring and inedible for engineering students expecting practical engineering approach to mathematics. On the other hand, especially because of the great drop-out rate in engineering education, some of the universities and engineering bodies, try to find the didactic methods to teach mathematical complex concepts with "practical approach", which means to connect the basics of mathematical concepts to practical engineering examples and projects. A joint effort of mathematicians and engineers, of teachers and researchers, is necessary in order to produce new, adequate, more efficient programs and didactical solutions in mathematics education for engineers.

The connection between different engineering domains and modern education is establishing interdisciplinary links between the subjects [1, 2, 3, 4, 5]. As a result, engineering education changes its focus from theoretical scientific approach to a mix of different disciplines (interdisciplinary projects), modeling, simulations and practical model building [6, 7, 8]. Great emphasis is placed on a combination of formal education, whose role is to impart systematic knowledge of basic disciplines, and informal education which is especially effective in broadening horizons, fostering curiosity, and active learning.

2. Mathematics for Electronics students at Copenhagen University College of Engineering

The learning method used at the Copenhagen University College of Engineering (short name in Danish is IHK IHK) is Project Organized Problem Based Leaning (POPBL), developed and used since 1974 at Aalborg University (AAU), in Denmark. The method is now used with great success in many countries all over the world [2, 9,10,11]. Many industrial companies in Denmark cooperate actively with technical universities in further developing and improving these methods in order to ensure that the future graduates have the necessary skills to develop their products. Considering the students' desire to work on real engineering projects and the requirements to master the basics of engineering, namely mathematics and physics, the message is clear: the students will be more likely "to stick with derivatives and integrals" if we can offer them some evidence of how necessary these tools are in order to find solutions for engineering problems. If we use this strategy from the first semester the students will see that they are already making progress towards completing engineering work/projects and the positive influence will be shown in an increased pass rate . There are different possibilities to involve students actively in the learning process:

- ➢ Using simulations programs involving graphics and animations in order to visualize the theory.
- ➢ Mixing the theory classes with practical exercises.
- ➢ Study-tours to industrial companies.
- ➢ Inviting guests from industry for lectures.

All the named issues are involved in Project Organized Problem Based Leaning (POPBL). The merits of the method are: extensive peer collaboration, increased motivation, experience in interdisciplinary problems and solutions, experience in working with real-life problems, and development of analytical skills [12,13,14].

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 Copenhagen University College of Engineering (short name in Danish is IHK) towards more projects and teamwork. Similar changes were made for all semesters in our programs, involving the basic courses in mathematics and physics. An example of our program in Electronics and Information Technology (EIT) is shown in Table I.
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 per day, one from 8:30-12 and one from 12:30-16:00.
Each semester the students carry out one or two projects connected to the theory they learned. During the semester, the students also develop the following non-technical/scientific skills:

- ✓ How to work in teams [11].
- ✓ 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 notation.
- ✓ Define and describe the fundamental methods for solution introduced in the course – using proper language and notation.
- ✓ 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.

Table 1: Program in Electronics and Information Technology (EIT).

ECTS	1. sem	2. sem	3. sem	4. sem	5. sem	6. sem	7. sem
2.5	OOP1	OOP2				Elective	
2.5			Electro-	DSM4	Practical Training training		Bachelor-
2.5	Project 1	Project 1	physics				project
2.5						Elective	
2.5							
2.5	DSM1	DSM2	DSM3	Control			
2.5				Theory		Elective	
2.5							
2.5	DIGE1	DIGE2					
2.5			Project	Robot		Elective	
2.5	Project2	Project2		project			
2.5							

OOP - Object-oriented programming
DSM - Digital Signal Processing and Mathematics
DIGE - Digital Electronics

During the first three semesters, students work on two projects each semester. The projects are connected to the basic theory courses they follow. Fourth semester project is an autonomous robot project, where the students have to apply all the theory they learned during the first three semesters of their studies. The robot project is the biggest project during the compulsory part of the undergraduate program [8, 9]. Mathematics or Mathematical Modelling is a part of each course and project. Other supporting tools in the learning experience are simulation programs. From the first semester the students are introduced to MATLAB and P-Spice programs. SIMULINK is introduced during the robot project. The use of simulation programs enhances learning potential and gives the students the possibility to test different mathematical and theoretical solutions. Simulation is also very important tool in project work, in design phase and before the practical implementation of their design into the working model. Simulation programs are very important tool to understand the role of mathematical concepts, to visualize different solutions and in order to choose the right values for their working model.
Students make evaluation of theirs courses twice during the semester, in the middle of the semester and after the examination. The evaluations include three parts: course evaluation, teacher's evaluation and general comments.
Students' evaluations and the results of examinations show an increased motivation to learn mathematics in this practical approach to the theory, especially for the students with previous practical experience. We have also observed much better understanding of all parts of mathematics curriculum during the first fourth semesters of their education. The pass rate is increased and the drop-out rate is decreased.

3. General about Math at Medialogy

Aalborg University established Medialogy study line for the first time in fall 2002 at the faculty of Engineering and Natural Sciences. The idea was to offer a university education at both bachelor and master levels in a combination of technical and humanistic subjects, like screen media, digital sound synthesis, sensor technology, perception, aesthetic, media sociology, computer graphics, human-computer interaction, interface design, etc., which would together enable the students to become "global problem-solvers in the technology world, independently on the problem"[15]. However, very soon it became apparent that the students who had enrolled into the education did not have enough mathematical skills to follow technical courses. Dropout rate due to this inability was very high. Thus, on students' request and with full agreement of teachers, the first Mathematics course at Medialogy studies was offered in fall 2004, and different mathematics courses have being part of Medialogy curriculum ever since. The study plans have being changed several times [16], and several teaching methodologies have being tried, also, varying from classical ex-cathedra teaching to project-oriented work. However, including mathematics into students' projects has got positive evaluation both from students' side (in the semester evaluation questionnaires) and in exam-passing statistics. One of the successful projects will be described in the following text.

3.1 Quality of Conference Papers and Presentations

This was a project on the 5th semester, when the students need to study Mathematics for Computer Graphics and Interactive Games, including elements of Linear Algebra and 3D transformations [17]. They needed to define a project where they would use those concepts. A group of students got interested into 3D optical illusions in 2D space, so they had analyzed several paintings of M.C.Escher, Oscar Reutersvärd, Rob Gonsalves and Jos De Mey, all of them being famous for "impossible" paintings. The students' attention was grabbed with Rob Gonsalves painting Tree House in Autumn, reproduced here on Figure 1. which relies on perspective dependent illusion that makes a small tree-house look just as a part of a large villa. After analyzing 3-focus perspective projection used for the painting, the students have concluded that the real scene in 3D looked like on Figure 2. The students modeled the 3D scene in Maya, and settled a perception test, where test-participants were given a possibility to explore 3D space, starting from initial position that showed a view like on Figure 1. They were asked to report when the illusion of two houses being a single one breaks – and, not surprisingly, got the results that the illusion breaks after only 2 degrees of counterclockwise rotation and 4 degrees of clockwise rotation around the vertical axle.
The students settled for a task to manipulate objects on the scene as much as they can, to keep the illusion as long as possible, without observers noticing neither that the scene gets manipulated, nor that the illusion breaks. They have used Emmert's law to manipulate the size of objects, and re-arranged the objects, including shadows, based on the observers' current position.

Description
This picture shows a house, which is present in two different planes. The proportions are very different from front to back of the house. The front is a tree house high up in a tree, and the back end is a three story building placed on the ground.

Figure 1: Rob Gonsalves - Tree House in Autumn.

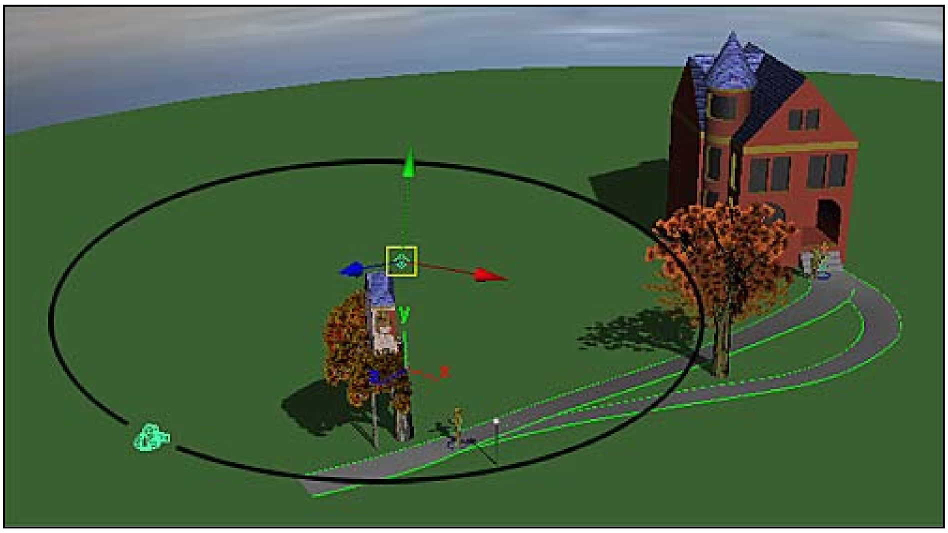

Figure 2: 3D scene – a black ring illustrating the camera animation

For example, the solution to the path and small tree animation was to group them with the person on the path, the lamppost and their respective shadows. This group was then attached to the brick house group and the rotation pivot moved to the end near the brick house. Finally the group was scripted to rotate counter-clockwise around the pivot, so that the path followed the brick house while, for most of the rotation, avoiding collision with the bigger tree. All these transformations, described by corresponding matrices, were defined and programmed in Maya's scripting language Mel.
The perception test was repeated with another group of people. On average, participants could turn the camera 31,39° to the right and 54° to the left before the illusion broke. This results in an average span of 85,39° within which the illusion works.
While working on this project, based on their initial interests, the students have gained understanding of 3D transformations, including perspective projection and motion description in 3D.

4. Conclusions

Copenhagen University College of Engineering (IHK) has since 1881 educated engineers on Bachelor level for needs of Danish industry, and also engineers recognized worldwide for their analytical and practical engineering knowledge. Aalborg University (AAU) is a pioneer in project-based learning. As AAU and IHK share the same physical location in Copenhagen – Ballerup, and the interests are common – how to engage and motivate engineering undergraduates to study mathematics, it was natural to combine experiences and share ideas for teaching methodology. We have decided to start on-going cooperation between our universities on mathematics didactics, and have decided to work together in order to improve the students' interest in mathematics. We have scheduled meetings 2-4 times a month to work on our project, starting from Fall 2010. Mathematics courses development at Medialogy department in Copenhagen have suffered from typical issues with new educations. The courses were established and changed in response to students' and teachers' observations during the years. In some of the study plans, mathematical courses have been standard university calculus and linear algebra courses, and in some study plans they have been tailored towards specific Medialogy student needs, but without taking into consideration actual level of previous mathematics knowledge of an average Medialogy student. Including mathematics into students' projects has shown that the students' engagement and enthusiasm for mathematics increases, as well as their ability to transfer mathematical concepts into real media-technology related applications. In the future we expect to gather statistical data to see the differences between previous run theoretical math courses and new project based learning including all necessary mathematical ingredients.

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