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Co-operation across Disciplines in Engineering Education Using Technical and Scientific Computing Environments

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The authors describe their project to reform the mathematics and computer science curricula in engineering degree programmes. This project focuses on the creation of defined links between mathematics and application-oriented engineering subjects in the introduction of technical and scientific computing environments in the teaching of mathematics, coupled with lectures in computer science, to enable engineering students/graduates to use this experience to solve problems. Experiences and results of the first year of project realisation are detailed.

INTRODUCTION

Information and communication technologies are bringing about an industrial revolution on the scale of that which rocked the 19th Century. The diffusion of these new technologies at all levels of economic and social life is thus gradually transforming our society into an information society. Mathematics is a living part of this society, and we cannot afford to experience it as a collection of formulas and rules for calculations. Amongst other things it is the language in which knowledge is expressed for use in computing, which is why our students must master the translation of commonplace knowledge into a precise mathematical description. It is therefore vital that students are introduced to modern tools of information technology as early as possible and constantly exposed to them. *Technical and Scientific Computing Environments* (SCE) are such tools. They have been available for several years and can be used in the teaching of mathematics at schools and especially at universities.

PROJECT BACKGROUND

Within the information society, there is an ever-increasing call upon expertise in mathematics and information science due to the constant development of industry and computer technology. In modern society, mathematics is increasingly used in almost all areas of human activity (methods for optimal resource allocation in production, transportation, management algorithms for maximising return on investment in banking and/or for trading in the stock-exchange, techniques for minimising waste when cutting expensive raw-materials like leather, textile or wood, simulation algorithms for computer-aided design in all areas of industry from bottle production to plane buildings, etc).

Mathematics and mathematics teaching are nowadays in a very paradoxical situation, with mathematics more or less regarded as a discipline that is accessible only to a small minority of so-called *mathematically-gifted* people. On the one hand, everyone recognises the usefulness of mathematics from the economic, social and industrial points of view, as well as from the point of view of modern cultures, which are grounded in science. However, mathematics teaching is not effective enough to ensure a sufficient level of competency for all those who will have to use maths in their professional life. Moreover, the negative image of mathematics, which is common in public opinion, prevents the dissemination of maths information and culture to a large public audience.

To enable graduate engineers to better meet the requirements of their profession within this changing environment, the starting point of the project to reform the mathematics and computer science modules in the mechanical and environmental engineering degree programmes in the Wismar University of Technology, Business and Design was the need to enliven and intensify the study of mathematics in the basic education of engineers.

Universities are having to accept students with poor mathematical knowledge and skills after secondary schooling, and it transpires that on this foundation, many students do not understand and cannot use basic theories on completion of basic studies in mathematics and information science [1]. Students seem to study and rote learn for the short term, ie for the purpose of passing examinations, without a deep understanding of the subject matter, so that knowledge is fleeting. They are frequently stumped, not to mention astonished, when, in their more advanced study of engineering, they are called upon to apply knowledge of mathematics and/or information science supposedly acquired in earlier years.

PROJECT DESCRIPTION

We also need to recognise that whilst formal mathematics is presented deductively, and we progress from the abstract to the concrete, human learning in mathematics, for most people, is the reverse. People learn from examples. They recognise patterns.

Against this background we have to change our teaching style to include real problems (rather than academic exercises), non-standard argumentation, the connection of mathematical concepts with situations from everyday life and the environment, as well as deepening knowledge and skills acquired from earlier subjects and networking them. Teaching has to be directed at recognising, understanding, life-long learning and acquiring.

The power of mathematical thinking is the ability to create concepts and models and to develop efficient processes and algorithms to solve concrete problems. We have to explain to our engineering students that this will be a major part of their work as an engineer.

The reform of the studies in mathematics and computer science in the engineering curriculum at the University of Wismar follows three steps:

- Thorough investigation and exploration of applications of, and experiences with, SCE worldwide.
- Working out and testing new content and methodology in education in mathematics and computer science using SCE.
- Evaluation and reworking of the concept and changes in the curricula.

Our objectives in this project are:

- To enable students to acquire the capacity for life-long learning, in part through a training of thinking that will provide graduates with the capacity, after decades of working, to be innovative in their professional area. To this end, lectures, exercises and seminars should not only be preparation for examinations, but they must also provide students with extensive mathematical knowledge and understanding, a wide range of mathematical methods for their professional area, and the opportunity to recognise and to apply logical structures.
- To increase the attractiveness of the mathematics and computer science modules.
- To combine the different subjects of the studies, starting with mathematics and computer science, in order to expose students early on to realistic engineering problems. In other words, applying mathematical and computer science methods from the first to the last year of study.
- To integrate professional oriented exercises and project work methods.
- To operate more closely, and from the commencement of studies, with scientific methods, solution-oriented methods and problem-solving techniques with the use of modern communication tools.
- To increase the independence of students by acquisition of knowledge using learning-software.

Our project is patronised by the *Stifterverband für die Deutsche Wirtschaft,* an organisation that encourages initiatives for the reform of German university education to better meet the needs of German industry [3].

PROJECT TREATMENT, FIRST EXPERIENCE AND RESULTS

The project to reform the mathematics and computer science modules in the engineering programmes started in 1997, and it was decided to use SCE MATLAB in these modules. MATLAB is a language of technical computing, which means that it is designed to increase the scope and productivity of science and engineering, to accelerate the pace of discovery and development, to facilitate learning and to amplify the creativity of research [4]. Advantages of the use of MATLAB are:

- Learning MATLAB statements is relatively easy for students; they can perform it and the results or the error presentation show them the correct usage directly.

- Often mathematical problems can be solved in a few steps; numeric and symbolic calculations are possible.
- MATLAB includes several tools to solve standard mathematical problems.
- The MATLAB programming language is simple in contrast to other programming languages (for example Pascal or C) and has powerful visualisation capabilities.
- Various control statements allow loops and branching.
- The subroutine concept is included in MATLAB till the recursive function call.
- The newest version of the MATLAB environment, MATLAB 5, includes all data structures that are needed to teach the foundations of computer science.
- MATLAB 5 vastly enhances programmer productivity, providing many ease-of-use and ease-of-learning features that enable the rapid development of larger and more complex applications.
- Arrays with two or more dimensions can be created and accessed.
- Object-oriented methods are possible; students can be introduced to modern programming methods, such as classes, operator and expression overloading. Methods that override existing MATLAB program files can be used.
- The large selection of toolboxes allows one to compare techniques and choose the right approach for the particular application. SIMULINK adds a block diagram interface and live simulation capabilities to the core numeric, graphics and language functionality of MATLAB. The Blocksets extend SIMULINK for use in specific application areas, while Real-Time Workshop provides code generation capabilities for target hardware.

In the first year computer science module the basic concept of MATLAB, the MATLAB statements and the control structures were introduced. The students solved first programming exercises. In parallel to this introduction, MATLAB was used as a tool for carrying out mathematical operations and solving mathematical problems in the mathematics module. 25% of the contact hours of this module took place in the computer laboratory. Students have a worksheet with problems for the laboratory work. They have to solve the problem(s), or rather *little projects*, in teams of two or three students. The problems concern mathematical and engineering subjects of past lessons, as well as exploring some concepts of following lectures. The teacher works as a supervisor.

Our approach to using computers and SCE in mathematics lectures and seminars was as follows. SCE should:

- provide a greater proportion of students with the opportunity to apply sophisticated mathematical methods in problem-solving;
- support concentration on modelling and problem-solving strategies in mathematics;
- allow the possibility to deal with larger and more realistic problems;
- not decrease the theoretical level of the mathematics curriculum;
- not be used instead of traditional textbook methods;
- be applied as a supplement to traditional methods;
- be used to stress the numerical methods in the mathematics curriculum;
- increase visualisation;
- be used for data analysis and to simulate technical processes;
- be used to verify solutions.

The use of technical and scientific computing environments in teaching raises the question of whether SCE makes parts of the standard mathematics curriculum redundant. It has been argued that with the advent of SCE and the widespread use of statistical packages, there is less need for students to have basic skills. Neither SCE nor statistical packages are expert systems. Before data can be entered into either, and again when the output is analysed, the user needs an understanding of basic mathematical ideas. It is very much a case of *garbage in–garbage out.*

While making some changes in the curriculum, it was decided to give up training of extremely specialised mathematical techniques and ineffective and time consuming routine work, for instance:

- special substitutions for finding primitives;
- the drawing of graphs and analytical discussion;
- manual repetition of calculation algorithms; and
- determining the shape of regions in connection with multiple integration.

More time is then available for the mathematical culture (tools, concepts, history) and the attempt to show that mathematics can be attractive, useful and intellectually exciting.

We believe that our first year students enjoyed the

MATLAB exercises of the mathematics module. Two of the best students joined our project team and supported us in the development of teaching-software which is used for demonstration purposes in lectures. Students of later semesters dealt with and finished the following interesting projects:

- Development of an interpreter for symbolic calculation.
- Development of a WWW-based access to MATLAB.
- Development of a MATLAB toolbox for the simulation of discrete event-oriented systems.

CONCLUSIONS

Cross discipline co-operation in engineering using technical and scientific computing environments supports traditional teaching methods with modern tools for problem-solving. It does not imply a reduction in the standard of education or to necessary subjects, but it is vital that the curriculum is carefully considered and that teaching ballast is rejected in favour of new methods.

First experiences show that:

- the attractiveness of mathematics and computer science to students of engineering is increasing;
- the acceptance of mathematics and computer science by students of engineering has improved;
- students better understand the teaching content of engineering;
- students have higher motivation for independent learning.

Students are also able to acquire the following general non-technical skills:

- Communication skills through the processing and presentation of project results in teams.
- Thinking in logical structures, principles of systematic approach.
- Independent acquisition of knowledge through using learning-software.
- Learning how to learn.
- Oral and written presentation techniques.

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BIOGRAPHIES

Norbert Grünwald was born in Rostock, Germany, on 5 October 1953. He studied mathematics at the University of Rostock, receiving the degree of Bachelor of Mathematics in 1979, and was awarded a doctorate, specialising in discrete mathematics, in 1984. Between 1984 and 1986 he was on the scientific staff of Deutsche Seereederei Rostock, a shipping line, before working as a scientific assistant in the Institute of Mathematics of the Warnemünde/Wustrow Maritime Academy. In 1991 he took up a scientific assistant position in the Department of Mathematics of the University of Rostock, and since 1992 he has been Professor of Mathematics and Operations Research in the Department of Mechanical Engineering at the University of Wismar, Hochschule Wismar, Wismar, Germany, where he is actively involved in the self-government of the institution.

Professor Grünwald has published several works and has been involved with a number of research projects and an expert report. He is a co-ordinator and jury member of the German mathematical Olympiad, and mentor for the German team for the international mathematical Olympiad. He is a member of Deutscher Mathematiker-Vereinigung e.V. and Mathematikolympiaden e.V. On the international front he is a member of the ILG-EE and of the UICEE Academic Advisory Committee.

Andreas Kossow graduated from the University of Rostock, Germany, as a mathematician in 1977, and received a doctorate in mathematics in 1981 and the Habilitated Doctor's degree in engineering in 1987. His main research field is applied probability theory. Currently, he is Professor of Mathematics at the University of Wismar, Germany.

Thorsten Pawletta is a Professor of Applied Computer Studies in the Department of Mechanical and Process/Environmental Engineering at the University of Wismar, Germany. His major research interests are modelling and simulation methodology, parallel and distributed simulation, and programming and engineering problem-solving with scientific and technical computing environments (eg MATLAB).

He teaches courses of Applied Computer Studies to engineering students, and object-oriented programming and complex software systems to computer science students. Prior to his appointment at the University of Wismar he worked for 6 years as a research engineer at the Institute for Industrial Automation, and for 4 years as Assistant Professor for Modelling and Simulation in the Department of Computer Science at the University of Rostock, Germany. He received a PhD in Applied Computer Studies in Engineering in 1991 from the University of Wismar. He is a member of the International Society for Computer Simulation and the German Society for Computer Simulation 1984.

Rolf-Peter Tiedt is a Professor of Computer Science and Applied Mathematics in the Department of Mechanical and Process/Environmental Engineering at the University of Wismar, Germany. He graduated from the University of Rostock, Germany, as a mathematician in 1968, and received a doctorate in mechanics in 1977 and Habilitated Doctor's degree in engineering in 1987. His main research fields are computer science and applied mathematics.

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