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Cross-Discipline Co-operation in Engineering Using Computer Algebra Systems (CAS)

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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 computer algebra systems (CAS) into the teaching of mathematics. 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 gradually transforming our society into an information society, and it is therefore vital that students are introduced early on and constantly exposed to modern tools of information technology, c*omputer algebra systems* (CAS) for instance. These have been available for a few years and are being used in the teaching of mathematics.

Project description

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. To enable graduate engineers to better meet the requirements of the 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 at the University of Wismar was the need both to enliven and intensify the study of mathematics in the basic education of engineers. As well as poor mathematical knowledge after secondary schooling, it transpires that many students, on completion of basic studies in mathematics and information science, do not understand and cannot use the basic theories [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.

Reform of the basic studies in mathematics and computer science follows these three steps:

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

Our objectives in this project are:

- To enable students to acquire the capacity for lifelong 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 [2].

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].

Analysis of international trends

Globally, university lecturers think about reformation of engineering programmes. A way to increase the mathematical, computer science and technical knowledge and understanding of students is seen in cross-discipline education through use of computer algebra technology. The introduction of CAS into engineering mathematics lectures and seminars naturally leads to an integration of the mathematics and computer science curricula. But lecturers using CAS in teaching engineering mathematics emphasise that defined connections between mathematics and a wide range of application-oriented engineering subjects have to be created. The development of cross-disciplinary projects involving mathematics as a significant feature has emerged as the learning activity that has achieved most success [4]. International analysis shows that CAS were first introduced into engineering mathematics units about ten years ago. For example, CAS Mathematica, Maple and DERIVE have been used in Australian universities since 1990; there are also forerunners in the United States, United Kingdom, India and the Netherlands [5]. In the last five years, CAS MATLAB has gained increasing acceptance in research and teaching.

PROJECT TREATMENT, FIRST EXPERIENCE AND RESULTS

The project to reform the mathematics and computer science modules in the engineering programmes commenced in 1997, and it was decided to use CAS MATLAB. 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 [6].

Advantages of the usage of MATLAB include the following:

- Learning MATLAB statements is relatively easy for students; in using it, the results or error presentations show them the right usage.
- 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 (eg Pascal or C) and has powerful visualisation capabilities.
- Various control statements allow loops and branching.
- The subroutine concept is included in MATLAB until 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 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 programme files can be used.
- The large selection of toolboxes allows one to com-

pare techniques and choose the right approach for a 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.

The basic concept of MATLAB, the MATLAB statements and control structures, were introduced in the first year computer science module, and 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, with 25% of the contact hours of this module taking place in the computer laboratory. Our approach to using computers and CAS in mathematics lectures and seminars was as follows. CAS 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 text book methods;
- be applied as a supplement to traditional methods;
- be used to stress the numerical methods in the mathematics curriculum;
- increase visualisation;
- be used to verify solutions.

The use of computer algebra technology in teaching raises the question of whether CAS makes parts of the standard mathematics curriculum redundant. 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.
- Manual repetition of calculation algorithms.
- Determining the shape of regions in connection with multiple integration.

It appears that the first year students enjoyed the MATLAB exercises of the mathematics module. Two of the best students joined our project team and supported the development of teaching-software that is used for demonstration purposes in lectures. More experienced students 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 computer algebra systems support 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 nontechnical 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.

REFERENCES

1. OECD, Zentrum für Forschung und Innovation im Bildungswesen. *The 3rd International Mathematical and Science Study* (1996).
2. Grünwald, N., Engineering education in the information society, and the reformation of a math-

ematics and computer science engineering degree programme. *Proc. 1st Asia-Pacific Forum on Engng. and Tech. Educ.*, Melbourne, Australia, 296-297 (1997).

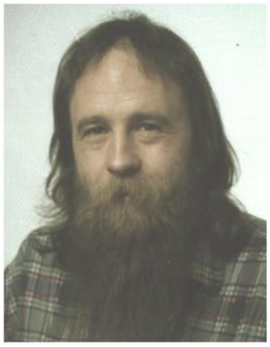
3. Stifterverband für die deutsche Wissenschaft, Memorandum und Aktions-programm: *Studienreform-Profilbildung-Wettbewerb* (1996).
4. Mays, H.u.a., Computer Algebra Systems: not just a tool for problem-solving but a language for teaching programme design. Report, Ballarat University College (1995).
5. Yearwood, J.u.a., Computer Algebra Systems and Implications for the Tertiary Mathematics Curriculum. Report, Ballarat University College, 6 (1992).
6. Matlab helpdesk of Studentversion of Matlab 5 (1997).

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.



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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.

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