

DEVELOPING MATHS AND COMPUTING SKILLS IN THE CONTEXT OF AN INTEGRATED CURRICULUM

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Abstract: This paper describes a mathematics and computing module provided for second year aerospace engineering students enrolled on the MEng programme – typically about 20 students. While it has been important to develop students' skills in these areas, the opportunity has also been taken to enhance integration across the curriculum.

The maths section of the course involves more applied topics such as linear algebra, vector calculus and Laplace transforms. Examples relevant to aerodynamics and engineering dynamics are included. Active learning is prominent during the classes. In addition to formal teaching, students work through example questions with the lecturer observing and available to assist.

The computing section is based on Matlab and builds on an introductory Matlab course. It aims to demonstrate application of the maths and show the usefulness of computing tools in aerospace engineering. The content was carefully designed to relate to the maths section and other second year subjects. For example, student exercises include plotting lift distribution on a wing, performing some structural analysis and investigating eigenvalues, before the course climaxes in a mini project on wing design.

Students found the Matlab section to be challenging. However, encouraging feedback indicates that most learn a lot from the course, they observe the applications for the maths and note the relevance to their degree.

Keywords: mathematics, computing, Matlab, aerospace, applications, integration.

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1. INTRODUCTION

The need of business and industry for well educated, motivated and skilled engineering graduates has recently been emphasised. The report also advises that engineering degrees should have an appropriate balance between technical understanding and practical application (The Royal Academy of Engineering, 2010).

The aerospace engineering degree programmes at Queen’s University Belfast include the core themes of aerodynamics, aircraft structures, flight mechanics, design and manufacturing. These are supported by topics such as mathematics and computing, systems engineering, electrical engineering, business and professional studies. There is emphasis towards application of engineering principles and there are opportunities throughout the programmes to develop a wide range of skills. Figure 1 shows some of the main themes and associated courses in the four years of the MEng degree. Within each theme, a coherent progression between courses in successive stages is expected – this could be described as “vertical integration”.

Stage / year	Theme				
	Aerodynamics	Design	Flight Mechanics	Structures	Mathematics and Computing
1	Fluids 1	Introduction to Aerospace Engineering 1	Flight Mechanics 1	Solids and Structures 1	Engineering Mathematics 1; Further Mathematics 1
2	Aerodynamics 2; Propulsion 2	Design 2	Flight Mechanics 2	Aircraft Structures 2	Mathematics & Computing 2M; Further Maths 2
3	Aerodynamics 3	Preliminary Design 3; Aircraft Design 3	Aircraft Dynamics 3	Aircraft Structures 3	CFD 3; FEA 3
4	Advanced Aerodynamics 4	Design and Simulation Integration 4		Aircraft Structures and Optimisation 4	

Figure 1: Selection of themes and associated courses in the MEng degree in aerospace engineering.

This paper is focusing on the mathematics and computing theme. In Stage 1 mathematics, it is aimed to provide students with a good grounding in a range of fundamental topics relevant to engineering and to demonstrate some application to real-world situations. It is also desired that students’ confidence in their mathematical ability should be enhanced. At Stage 2, in the first semester Mathematics & Computing course, students are introduced to Matlab and learn some basic operations and functions. This is built upon in the second semester Further Maths 2 course where more applied mathematics topics are presented and application of the computing tools to aerospace problems is explored. In developing this course, it was intended to relate to other subjects within the degree programme – “horizontal integration”.

The aim of this paper is to describe the Further Maths 2 course and to investigate the learning experiences of the students.

2. COURSE STRUCTURE AND TEACHING METHODOLOGY

The Further Maths 2 course has existed in its current form for three years. It is compulsory for second year aerospace engineering students enrolled on the MEng programme – typically 15 – 20 students each year. The teaching staff (the authors of this paper) are from aerospace engineering.

Class time consists of 24 hours of maths teaching (over the 12-week semester) and 15 hours of Matlab computing (a 1-hour lecture followed by a 2-hour laboratory each week during weeks 1 – 5). The maths is assessed by a 2-hour exam contributing towards 80% of the course mark. The computing is assessed continuously with five short structured assignments worth 2% or 3% each and an open-ended design question worth 8% in the last week.

The maths content involves more applied topics including linear algebra, multiple integrals, vector calculus and Laplace transforms. Examples relevant to aerodynamics, structural analysis and engineering dynamics are presented. The aim is to develop a sound understanding and practice of essential mathematics tools used in engineering.

The 2-hour lecture slot each week contains a combination of formal teaching and student work on example questions. The latter activity is introduced as appropriate, for example at the end of a topic, and students have opportunity to practise what has been taught. This keeps students alert and allows feedback (both for themselves and the lecturer) on their progress. Students consulting with their peers on the questions is not discouraged – their learning can be enhanced through the explanation of another. Having a mixture of activities during the class is also advantageous in that it simply breaks up the 2-hour session, helping to maintain student attention and involvement.

Even during the formal teaching sessions, student participation occurs with students asked for answers as a worked solution is developed. This can be achieved relatively painlessly given the small class size and the fact that the students know each other very well.

The first semester computing course involves the basic workings and functions of Matlab. For almost all students, this is probably their first introduction to Matlab. The computing in Further Maths 2 follows on from this and aims to encourage a systematic approach to problem solving and apply the maths and computing tools to aerospace engineering.

Students' skills are built up in the early weeks as the course covers loops, functions, writing to files, good programming practice, etc. These skills are then applied to aerospace engineering problems, for example estimating the lift on a wing and using this to calculate the torsion in the wing structure. Some time is spent manipulating matrices, solving sets of equations and calculating eigenvalues to help understanding of these topics which also occur in the maths section. This leads to the final project, a more loosely defined problem on shear force and bending moment for a wing. This involves tasks based on what the students have learned so far but they are now expected to interpret and plan the steps themselves. With the deliberate exception of this final project class, there is plenty of interaction between lecturer and students in the lab sessions with students able to receive individual attention.

3. STUDENT LEARNING EXPERIENCE

Student performance in both the maths and computing sections of the course has been good with typical average marks of 65% and 73% respectively. This level of achievement is to be expected of MEng students.

Comments written by students on questionnaires showed that most recognised the relevance of the maths, especially to aerodynamics and propulsion. They indicated that they gained a better understanding of the various maths topics and had learned new methods.

“Really helps for aerodynamics and parts of propulsion.”

“Clear link between maths being taught and the other modules, especially aerodynamics.”

“Greater ability to apply maths to other modules as aside from just within its own module.”

The students seemed to enjoy the style of teaching.

“Breaks and tutorial questions help break up session and keep my attention span.”

“Good explanations and examples to reinforce information being taught.”

“Clear and concise, structured, good support for examples.”

“Good, involving, how teaching should be.”

These views are reflected by a relatively high rate of attendance at classes. Data for previous years is unavailable but in the current year, attendance at the maths classes averaged 78% over the semester.

Aspects of the computing were found to be difficult. The application of Matlab to the aerospace design project was particularly challenging. However, students were able to identify personal gains from the course. It is interesting that some students focused on subject-specific skills while others mentioned transferable skills.

“Ability to more clearly structure my approach to problems and be more methodical in solving them.”

“Troubleshooting skills, breaking down engineering concepts into Matlab code.”

“Understanding of practical uses for Matlab.”

“Better understanding of how to apply Matlab commands.”

“How to analyse and work through more complex problem.”

“A better understanding of Matlab. Second part allowed for better and useful programmes to be written.”

It is also noteworthy that some students could deduce why an assignment might not be tightly defined.

“Sometimes not defined specifically, however this may be to show various ways of achieving an answer.”

“Freedom of finding ways to solve problems.”

A variety of responses was received concerning the relevance of the computing section. Most students noted the aerospace applications and links to other modules in the degree programme – structures, aerodynamics and design were mentioned. A few were not convinced that these links were of much significance. Interestingly, one student stated that the main relevance for him was that it prompted an improvement in his approach to problem solving in general.

“Tied into a number of modules both past and present.”

“All applications were aerospace orientated.”

“It changed my approach to problems. I feel more comfortable in my approach to problems in any subject.”

The authors believe that the current approach represents an advance in the teaching of computing. Previously, the computing coursework was heavily dependent on aerodynamics (the lecturer at that time was an aerodynamics specialist). Students disliked this, complaining that a sound understanding of aerodynamics theory was necessary to attempt the computing project. They felt the assignments were complicated and their coding ability was insufficient. The current methodology, involving a gradual building of computing skills and a wider range of aerospace applications, is thought to be more effective in developing students' skills.

4. CONCLUSIONS

The Further Maths 2 course is provided for second year aerospace engineering MEng students. The maths section of the course contains applied topics including linear algebra, vector calculus and Laplace transforms. The computing section is based on Matlab and aims to apply the maths and computing tools to aerospace engineering problems. In addition to enhancing students' skills in maths and computing, it is desired to connect with other subjects across the degree.

Most students recognised the relevance of the maths, especially to aerodynamics and propulsion. They believed they gained a better understanding of the various topics. They seemed to enjoy the classes which involve both formal teaching and student practice, keeping students involved.

Implementing a solution to the design project in Matlab was found to be challenging. However, students noticed benefits of the course, both in terms of improved programming ability and learning a more methodical approach to problem solving. The aerospace applications and links to other subjects in the degree programme were observed.

It is concluded that the course makes an important contribution to developing students' skills in maths, computing and general problem solving. There is some success in promoting integration between various subjects across the curriculum.

5. REFERENCE

The Royal Academy of Engineering, 2010. Engineering graduates for industry. *The Royal Academy of Engineering*, London, UK.