Specialist Software

Use of Mathcad to Assist in the Teaching of Second Year Engineering Mathematics

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Abstract

Mathcad is used in all years of the engineering mathematics course to enable students of civil engineering to investigate real engineering problems which have no analytical solution but which illustrate important mathematical concepts. In the second year engineering mathematics course Mathcad is used to assist in the teaching of numerical solutions of second order boundary value differential equations. Comparisons are made between classical analytical solutions and the numerical solutions.

Level of Material: Second Year

The Execution

In order to motivate the students to study engineering mathematics, problems drawn from other subjects studied in the degree are presented which require analytical and numerical solutions. An assignment is given to students early in the course which poses a problem drawn from structural engineering. It comprises a variable coefficient second order boundary value problem relating to beam-columns. The problem requires students to derive a set of finite difference equations for a limited number of internal nodes and solve the linear system of equations produced using Mathcad. Once this simple exercise has been undertaken the students have to extend their calculations to larger numbers of nodes and compare the results with approximate analytical solutions of constant coefficient differential equations which bound the true solution. The final part of the assignment which is normally only undertaken by students seeking high grades consists of then writing a Mathcad program using a 'shooting algorithm' for the same problem.

The exercise has the objective of making students realise that mathematics has a role in engineering, enabling practical problems to be solved. It revises the theory of second order differential equations which is needed at the end of the course when partial differential equations are encountered. It also extends their knowledge of Mathcad and its applications and consolidates finite difference theory.

The requisite mathematical knowledge, such as numerical methods for the analysis of differential equations, is taught by a series of lectures in parallel with the problem being given to the student. Additional Mathcad techniques required for the assignment such as handling large arrays are taught in problem classes.

Pre-requisite Knowledge

In the first year of the Engineering Mathematics course the students are introduced to Mathcad by an exercise which instructs them in some of the facilities of Mathcad such as equation solving, function plotting, etc. Students who enter the course directly into the second year frequently have not encountered Mathcad. A special demonstration of the facilities is given to these students and to all other students requiring revision or who did not fully understand all the features used in the first year.

The only other knowledge required of students before the second year is the solution of constant coefficient second order differential equations. This is taught to all first year students and is a pre-requisite for all students entering this module. Direct entry students into the second year without this knowledge are required to trail the course and study the first year module where this is taught.

How Are Students With Different Mathematical Backgrounds Supported?

By the time the students encounter the numerical solution of second order differential equations they have studied at least one prior mathematical module. Students from non A-level backgrounds are required to study an additional module in basic calculus techniques. Weak A-level students are counselled to take this module. During these prerequisite modules all the mathematical techniques required for the assignment not taught in the final engineering mathematics module are covered. Tutorials, surgeries and problem classes are used to develop necessary skills.

What Support Was Needed?

Courses in Mathcad are available from the suppliers Adept Scientific Ltd at regular intervals. However, Mathcad is reasonably easy to learn and the author trained himself very quickly. Technical advice on Mathcad is available from Adept and the suppliers are quick to respond, particularly to new users. Students using the software obtained tutorial support from the lecturer by e-mail. Additional support from the University Computer Centre would have reduced the academic demands but unfortunately there was no one in the centre with the skills to help. The University's response to the lack of support is that technical software can only be supported by the departments using it. Their support is for general purpose software such as Microsoft Office.

The Engineering Mathematics Course is taught by a specialist engineering mathematician with additional tutorial assistance provided by postgraduate research assistants.

The Barriers

The barriers to using Mathcad to enable the teaching of concepts of mathematics are firstly that some students are mathematically weak and see the computer as a hurdle to further progress and secondly that some students like to compartmentalise knowledge and do not want to make the effort to see the inter-relationship between different disciplines.

The weak students are encouraged in tutorial classes by making them appreciate the advantages of knowing the answers to mathematical problems before attempting to solve them. This increases their motivation and reduces resistance.

By being a practising mathematician researching and consulting in engineering I am able to give practical examples of the needs of Industry. This knowledge and appropriate examples tends to motivate, particularly the weaker students. Interestingly enough, mathematically strong students often would rather solve difficult mathematical problems than solve simpler problems which require interrelating different subjects.

If considering taking on this approach academics teaching engineering and science students should be encouraged to seek out problems from the subject specialists and integrate with the subject teams.

The Enablers

The major enabler for the course was the availability of the lecturer to get students over the initial hurdle. Once that had been achieved then students were sufficiently motivated to succeed. In addition sufficient terminals supporting the software had to be available and an appropriate support structure put in place.

Evidence of Success

The use of Mathcad has had two positive results. Firstly, students undertaking projects and assignments in the final year often use Mathcad without being prompted, even in preference to Excel. Secondly, because to program the finite difference equations meant that students had to get a full understanding of the technique, the coursework and examination components had better results.

How Can Other Academics Reproduce This?

Resources must be devoted to ensure that enough copies of the software are available so that students can always log on to use the package. Note that although the work reported here has used Mathcad, any computer algebra package which can undertake numerical calculations can be used.

Time must be spent in developing the assignments so that the students can see that the topics are relevant to their subject discipline. The assignments must then have a relatively simple starting point so that the students can achieve an initial encouragement before embarking on the full task.

Time must be allowed for students to learn the elements of Mathcad before being given too complex a task. In the current course this is achieved by teaching Mathcad in the preceding year to the major assignment.

Quality Assurance

All courses in Civil Engineering at Oxford Brookes University undergo annual feedback when all components of teaching and assessment are reviewed. The reviews of the Mathematics courses have commented favourably on the Mathcad components as providing relevance.

Other Recommendations

My main recommendations about using computer algebra packages to assist in the teaching of mathematics to scientists and engineers are:

■ Produce a set of graded exercises to ensure that the students are fully familiar with the package before starting the assignment.

■ Make sure that the assignment is subject specific and integrates several different topics.

■ Provide enough copies of the software.

■ Get other members of the subject team involved with selecting the assignment so that it is seen by students to be part of their subject development.

■ Ensure that sufficient technical support exists so that student problems are solved quickly.

References

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