Multiple Approaches

Using Technology to Teach Mathematics to First Year Engineers

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Abstract

This case study reports on the approach at one institution to helping first year engineering students to acquire the mathematical skills they need. The approach involves a range of support mechanisms, and the concerted use of technology as well as paper and pencil methods. Changes in curriculum, pedagogy and indeed assessment style have all proven necessary.

Level of Material: First Year

The Execution

Mathematical topics are treated according to 'SONG' – a combination of Symbolic, Oral, Numerical and Graphical approaches – broader than the traditional mainly symbolic approach, and in the same vein as with the Calculus Reform movement in the USA. Students are encouraged to engage in *doing* mathematics, and to exploit a range of technology throughout – graphics calculator, spreadsheet, Derive, pencil, etc. The rich interplay of graphic, symbolic and numerical approaches is emphasised. Technology empowers students to check their own solutions. Sometimes, mathematical ideas are introduced via modelling of an engineering situation. The 'Oral' refers to communicating mathematical ideas, formulating engineering problems and communicating the solution appropriately. Some relevant modelling case study assessments are thus used – with students encouraged to take full ownership of the problem, with some marks being given for demonstrating various key skills. Examples appear in the references.

Pre-requisite Knowledge

There is a widely recognised problem with what can be assumed as pre-requisite knowledge and skills for engineering students newly arriving at university. The problem arises from a complicated set of circumstances including: changes in pre-university mathematics, the diversity of backgrounds of students entering university, the need for development of curriculum (and staff) to make university expectations realistic and the impact of technology on what is really required. We hope for a certain level of numeracy, including sensible use of a calculator, a certain fluency in algebraic techniques, and some previous acquaintance with the ideas of the calculus. Many students in the group do not have A Level Mathematics, so we are frequently disappointed. It is a major task of the module to get the students to revisit and enhance previously encountered topics as well as moving onto new topics. The diagnostic plays a role here. We do not use the word *remedial* because of the possible stigma – each student revisits topics according to need.

Given the diverse intake, the module must strike a balance between, on the one hand getting students to cover the ground as laid out in the module document and on the other allowing each person to start from a position which makes sense to them individually. The curriculum is challenged by technology anyway – for instance how much of the traditional range of paper and pencil integration techniques must now be covered on paper before we will allow our students to feel comfortable with widely available CAS systems? We hope that students will benefit from a fresh approach to topics with which they may not have been entirely comfortable previously and we believe that motivation and interest are important alongside pre-requisite knowledge.

How Are Students With Different Mathematical Backgrounds Supported?

The whole module is predicated on a diverse intake, but there are additional measures in place. There is a range of support materials on paper and on-line, covering both module material and surrounding or prior topics. The initial diagnostic can set an agenda which can be supported through standard tutorials, the drop-in Maths Help, extra targeted tutorials and additional credit-bearing modules. Each worksheet has a range of problems and activities, with the aim of stretching the more advanced students, while giving all something in which to engage.

What Support Was Needed?

Key staff participate in, contribute to and learn from international conferences and national events, to exchange ideas and practice and to widen their perspective. Continuing funding and time is needed for this. In fact time for reflection and to interact with the academic community is the main resource needed. Tutorial staff and engineering staff affected by changing student skills have participated in local developmental events, for example, giving the opportunity to explore the implications of the technology. IT support is required to load, maintain and update software.

The Barriers

Students have preconceptions of mathematics and a broader approach which requires them to engage fully can provide a challenge for some. Some say, "I don't like to use technology until I understand the basics", but upon investigation it is not clear what "the basics" are. Some say "technology is just pressing buttons", failing to understand the challenging message that technology can help focus on the mathematical idea (although some do want to be taught which buttons to push!). Many students do not recognise the contribution this approach to mathematics can make to key skills development and tend to compartmentalise mathematics anyway.

Some staff have displayed a certain resistance to change, although when they explore and reflect on the philosophy and approach, the reservations often focus in on an unease about assessment. There are various examples of this: the use of calculators in examinations and the possibilities for "hiding" facts in the memory (but should we be testing memory?); or the value or otherwise of radical ideas such as learning diaries, which may enhance key skills and encourage more thoughtful learning, but which from a narrow focus may be seen as a distraction. Some staff found the loss of control – with students knowing the technology better than them – a difficulty.

The Enablers

The most important enabler is *enthusiasm* amongst staff. This has been an interesting experience of innovation, with the ideas being spread from a small group and adopted and adapted progressively and variously amongst both mathematics and engineering staff as they have had time to gain experience and to reflect. Small successes help things along, such as a student finding a novel way to solve a real engineering problem using technology, or an engineer seeing a way of integrating the new approach into a laboratory. It is important to be willing to discuss the approach openly with students, and we believe this reflection is an important part of learning.

Evidence of Success

We can only report qualitatively: to report on any improvement or otherwise in exam performance is not helpful as the nature of the assessment is changed when students are empowered by technology. As with all approaches, some students fare better than others – and it is best with those who engage fully. These latter have produced some remarkable work. Evaluation through quality systems, questionnaire, learning diary, and a more concerted set of group interviews give the diversity of views which might be expected. We do not claim to have the answer, but we have embarked on a very interesting learning process.

How Can Other Academics Reproduce This?

The main point is to reflect on the approach and how it might make a contribution within each person's context. Some might feel able to go further than others. But our experience is that if you wait for all to agree before you try something innovative then you will never change. To learn from and improve an innovative approach you need to try things and gain experience. Computers have been with us (and our students) substantially and increasingly for 40 years, and now real power is widely available and even hand-held, then we must deal with it. It is possible to experiment incrementally to some extent, but there comes a point where, for instance, someone has to propose and decide that graphics calculators are allowed in examinations.

Quality Assurance

Module feedback forms covering all aspects of Teaching Learning and Assessment (TLA) give scores much in line with other modules.

Other Recommendations

- Share ideas and materials, and be honest about both successes and difficulties.
- Put key handouts on both paper and as electronic files, but have a variety of other materials.
- Don't imagine any one thing – diagnostic, computer based learning, virtual environments, technology, drill and kill …- will solve all problems. The one universal thing is that students need human contact to help them face up to their mathematical problems.
- Present a range of approaches both technological and traditional and take account of diverse students with varying learning styles. You can bring them all to water, but some prefer it flavoured!
- Come and talk to us if you are interested!

References

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