criticisms, but a glance at a few copies of CMP quickly dispels the second. Currently there is some three to four times as much material, at least, being published in General Topology (54) as in Algebraic Topology (55). So it certainly is not dead - or maybe it just refuses to lie down!

Sophisticated information retrieval systems are certainly a great boon to those researchers to whom they are readily and cheaply available. Their existence and use by some in technologically advanced countries, however, makes it more, rather than less, incumbent on all workers in a competitive environment to be aware by some means or other of what is going on. As in the case of the law of the land, ignorance is not a defensible position. In these days of zero, or even negative, library growth, CMP can go a considerable way towards compensating for funding deficiencies in libraries. If used flexibly, it is an effective and cost effective tool for use by anyone engaged in research in the mathematical sciences.

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MATHEMATICAL EDUCATION

COMPUTERS AND THE TEACHING OF MATHEMATICS TO TECHNICIANS

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This article is a personal reflection on the direction that my teaching, and that of several of my colleagues, has taken in the last few years at Waterford Regional Technical College. The majority of my teaching has been to engineering technicians, and hence a certain bias will not go unnoticed in what follows. Oddly enough, the use of computers in the teaching of mathematics is perhaps not so entrenched in Science or Programming courses as it is on the Engineering side. This is partly due to the syllabi, and partly due to the fact that it has not been seen as part of the mathematics lecturer's role that he/she should get involved on the computing side of things. Nevertheless, given the nature of such courses, it would seem that the sort of mathematics being taught should be very amenable to computer implementation and investigation. My own impression is that personal preferences have been the deciding factor. This is perhaps borne out by the fact that the Physics syllabus on many Science and Programming courses is backed up by a computer-assisted tutorial system which has proved its worth over a number of years.

Before the establishment of the RTCs, the standard level of 'mathematics' that was the daily diet of technical students amounted to little more than mensuration. The fact that nowadays the minimum mathematics qualification is a Pass D in the Leaving Certificate has allowed educators to raise their standards. The presence of professional and degree courses in several RTCs has led to a much more sophisticated type of mathematics being available, and this is certainly bound to have its effect on the Certificate Level courses.

However, the challenge that most lecturers face can still seem daunting. On many technician courses, the majority of students may only have the minimum requirements in mathematics - a Pass D. The fact that a number of these may well have been E's before statistical adjustment means that basic numeracy cannot be taken for granted. To bring a class of such students to a level somewhat beyond Leaving Certificate Honours level in one year can sometimes seem an awesome task especially when many of the topics are so new to them. Experience shows that the first year is the 'make or break' year - students who pass into the second year of their studies seem quite well able to handle levels of mathematical sophistication, often higher than their Leaving Certificate results would seem to indicate possible. (This in itself would seem to raise questions about the way that school mathematics is taught.)

Fortunately, the development and expansion of the RTCs has been paralleled by the increasing use of computers in education. Waterford RTC has well established computer facilities - a VAX 11/780 and micros - which were originally the domain of the courses in computer programming. However, early on, the need for most technicians to have some knowledge of programming was perceived, and hence most courses had a simple programming/computer architecture module attached. Invariably, it was the mathematics lecturer who was charged with these modules. It was natural that these lecturers should seek inspiration for their programming exercises in the mathematics that they were teaching. Hence mathematics was a source of exercises for programming. Gradually, however, the emphasis is changing, and increasingly the computer is being seen as a vehicle for the teaching of mathematics. Computer modelling of mathematics is becoming the bridge that allows the weaker student to come to grips with the concepts that heretofore left him/her baffled. An example of this is the limit process, which has normally been assumed to be beyond the grasp of the majority of first year technician

students. The computer investigation of a few well-behaved limits soon clears that up. The 'delight' on the faces of students as the numbers whizz up the screen is a quiet revolution that is taking place at this level. The limiting process becomes tangible, or at least acceptable.

However, the selling of mathematical concepts is still hard when numerical output is all that is available. Once again, few technician students can make the leap from a set of numbers to a picture of what is going on - especially when a mathematician's superior analogue powers are perhaps what makes him what he is. Fortunately, computer technology (and its falling prices!) provides an answer in the guise of computer graphics. Functions come alive on the graphics screen. Suitably written software allows functions to be added, multiplied, translated, integrated, convoluted - you name it - directly in front of the student. How many mathematical undergraduates ten years ago could 'play' with Bessel functions the way a second year Electronics technician student can do now? We are seeing the Fast Fourier Transform become a friend, multiple regression become routine, stiffness methods a practicality.

The fact that the computer can come up with the 'right' answers once the student has mastered the concepts, and the increasing availability of suitable software (homegrown or bought), poses a profound question on the direction and future of technician mathematics, and by extension, the role of the teacher in this context. Is it more important to be able to differentiate exp(-x)sin(x)cos(x) than to describe what differentiation is? Ideally both are equally important, indeed it can be argued that you cannot have one without the other. However, I have seen classes 'calculate' such derivatives with consummate ease, and yet only a minority could give a satisfactory explanation of what they were doing, and its possible uses. My own fault, of course. Nor do I claim that computers are the answer. More time, better explanations, better motivation are part of one. But in the absence of at least two of these, the computer surely can help. It frees us to sell the concepts, and lets the students get on with the exploratory modelling that reinforces them. What should we then examine? And what happens when the staff whose courses we are serving find that they have a new breed of student, with vast amounts of (computer-based) mathematical firepower that some at least are only too anxious to use?

At Waterford RTC, the Engineering Department has made a concerted effort to integrate the computer with all aspects of technician learning. The mathematics lecturers who service this Department have been more or less eager to help. The benefits are many - concepts can be taught rather than sterile methods, self study takes on a new meaning, algorithms become important - in short, the student begins to think about what he/she is doing. Students acquire a taste for mathematical modelling, with the inculcation of a 'what if' mentality being reinforced by immediate response in many cases. New functions are investigated with the same (almost!) enthusiasm as new equipment.

A welcome consequence which may not be immediately predictable is that overall numeracy increases. I hesitate to analyse the reasons too closely, but presumably the student feels more in control, and more motivated to get things right. The investigation of an algorithm leads to clearer thinking than the brainless application of a 'method'. The computer interface is more encouraging perhaps that the human one, with all the remembered connotations of correction and humiliation that can go with it. The 'inhumanness' of computer messages leaves them free of judgement, and thus more acceptable and more likely to instigate a fruitful line of thought. Another, more mundane reason is that if the computer is used effectively, concepts are grasped more quickly and more class time can be spent on problems. The computer can draw the sine graph far quicker than I can, and with suitable animation

techniques, phasors can be explained in far less time than a normal chalk and talk session takes. Hence one is left with more time to do the calculations.

Purists, of course, may argue differently - but then, most purists are involved in the formation of pure mathematicians, or at least they should be. It may be argued that nobody who is not familiar with the concrete implementation of their discipline should be let near those who will in fact spend most of their lives on the 'implementing' side. The fact that in universities there are 'pure mathematicians' teaching 'maths methods' courses has more to do with the constraints of timetabling and the need to earn than any pedagogical argument in its favour, and presumably only the greater intelligence of university students buffers them against the damage that this can do. Indeed, voices raised in this Newsletter would seem to indicate that this 'greater intelligence' can no longer seem to be taken for granted, and certain university courses are seeing the same level of student (as regards mathematics, at least) as is the norm in the RTCs. Fortunately, not all purists are Luddites, this being borne out once again by previous articles in this Newsletter. The beneficial effects that take place when the 'pure' meets the 'applied' may then be seen - the software gets better, and the teaching more efficient. Paradoxically, the computer investigation of mathematical methods may yet be our best bet in giving mathematics a 'human face' to those who have been unable to see it.

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