Teaching mathematics across the undergraduate curriculum: explanations of successful and failing teaching experiences

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This paper provides a rationale for a forthcoming research project (anticipated 1998 - 2000) in which, broadly, it is intended to attempt to define circumstances associated with successful mathematics teaching and learning at university level, and to examine the issues from the perspective of those who are teaching mathematics, paying particular attention to the accounts of non-mathematics specialists.

Mathematics as a core subject or skill permeates the curriculum at undergraduate level, just as it does in schools and also in vocational further education and training. Thus there is, or shortly will be an even greater demand for teachers of mathematics to work with the students who need it to be taught. However, at advanced level in school, and at undergraduate level in university, fewer people are electing to study mathematics, despite an overall massification of higher education, suggesting a smaller pool of qualified mathematicians from which to draw teachers.

At university level, a general crisis exists in terms of the mathematical competence of apparently three distinct undergraduate populations: students of mathematics; students in mathematics related courses such as science and technology which require specific algebraic skills; students in less obviously mathematics related courses such as psychology which require data handling and interpretative skills.

Experience from other sectors of education suggests that as the need arises, non-specialist mathematicians are drawn into teaching mathematics, with varying degrees of enthusiasm. For example during the mid to late 1980s, I was involved in two initiatives to support non specialist mathematicians teach mathematics: a course of retraining offered to teachers of subjects not in shortage for them to transfer into mathematics teaching; the other a project to develop materials to support young people on Youth Training Schemes and their craft supervisors to deal with 'off-the- job training' in 'numeracy and problem solving'. Both groups of teachers to start with at least were primarily concerned with their own mastery of the mathematics that they were required to teach. However, I have since begun to think that many non-specialist mathematics teachers move beyond this pragmatism, and may be characterized by range of approaches to and beliefs about successful mathematics teaching. So far as I know, little attention has been paid to approaches taken by these teachers in the standard discourse of mathematics educators (through professional associations etc.).

The university where I work as a lecturer in mathematics education, draws undergraduate students from the South East of England. Students come from local schools. In 1998* there are approximately 520 teaching staff and 6,700 undergraduate

* Data from University Facts and Figures 1997-8, available from the University Information Office

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students, of whom 572 are studying mathematics, 2,200 mathematics related courses such as Science or Engineering, and a further 2000 on courses which are likely to require some level of mathematical competence, i.e. Social Sciences and Business. Using an overall staff: student ratio of 1:12 as a very rough guide, I suspect there may be as many as 40-50 specialist teachers of mathematics and up to 350 staff who may teach some mathematics to meet the needs of students on courses which need particular mathematical competences.

In Britain since 1980, the undergraduate population has increased approximately tenfold. We can parallel the massive increase in Higher Education with a decline in the workforce. Once upon a time not so very long ago, very few would enter university whereas thousands were streaming out of the factory gates. Now the workplace is likely to be more solitary, but the examination halls are bursting at the seams (Wolf, 1996). In this context, university lecturers are faced with bigger classes, more students, a wider range of ability. Schools on the other hand are preparing more people for higher education, and fewer for 'everyday life'. Indeed 'everyday life' for many young people is higher education, and furthermore, a further education in which study of some mathematics forms an explicit part. Despite this overall expansion, the number of students choosing to study mathematics at university is relatively falling. Numbers of post-16 students studying for straight mathematics A-levels, that is double Mathematics and Physics, are falling too (Fitz-Gibbon and Vincent, 1995).

Criticism of the way mathematics is taught is not new. However, it is now coming from an extended range of sources. Some mathematicians claim that the mathematics students at university show:

(i) Serious lack of technical facility - the ability to undertake numerical and algebraic calculation with fluency and accuracy;
(ii) Marked decline in analytical powers when faced with simple problems requiring more than one step;
(iii) Changed perception of what mathematics is - in particular of the essential place within it of precision and proof.

(Tackling the Mathematics Problem, London Mathematical Society 1995)

There is also criticism of the mathematical understanding and facility with which students in mathematics-related courses are able to tackle context specific mathematical problems in their subject studies. Here a major difficulty is expressed by lecturers in mathematics related subjects such as Economics and Biology, who describe how the disappearance of specific topics from the school GCSE and A-level syllabuses have serious ramifications later on. Indeed fears of the lecturers are substantiated by the comments of external examiners, to the extent that at my university the University Academic Audit Committee in 1997 required a full cross-campus 'assessment of the problems stemming from the deficiencies in mathematical knowledge and abilities of students admitted to programmes in science and all data handling disciplines'. It does seem likely that in the face of the apparent extent and breadth of the problems that what is seen as appropriate mathematical knowledge will vary from context to context. Algebra has already been documented as poorly understood or applied in the context of Science, but it is unlikely

that this problem will be as significant in for instance Psychology as the ability to interpret data and construct appropriate inference or argument.

The construction of a curriculum, be this at school, in the context of workplace learning, or at a university of college, reflects the desires and aspirations of the society , as well as shaping them. A full discussion of curriculum and culture is outside the scope of this paper at this stage. Here it is enough to draw attention to one specific point. In England and Wales we have adopted the rhetoric of what has been called a commonor entitlement curriculum (see for example Lawton 1989) which reflects the notion that there are different aspects of human experience to be promoted in schools (scientific, aesthetic, logical, etc.). Following a series of recommendations by Sir Ron Dearing into post-compulsory education, all students thereafter, with the exception of those doing A-levels, are now required to do some mathematics post-16 on their GNVQ or NVQ programmes. A-level students intending to enter university are likely to have achieved Grade C at GCSE* . It would seem that whatever mathematics is being studied in schools and colleges, by all students at all levels, it is the wrong mathematics.

During my career I have worked with a number of groups of non-specialist mathematics teachers. When I was a school teacher, I worked with teachers of other subjects so that they could come in and support the mathematics teaching in the school. Later on in another job, I worked with YTS supervisors who had to teach mathematics as a core skill in the training offered to trainees (Drake, 1991). My master's dissertation documents the changing attitudes to mathematics exhibited by a small group of teachers who were retrained over the course of a year from being teachers of other subjects (Drake 1989). More recently, at a workshop in Zimbabwe I led a SWOT (strengths, weaknesses, opportunities, threats) analysis with a group of Teachers College lecturers. All the lecturers were preparing teachers for working in primary schools in Zimbabwe, and all teachers in primary schools in Zimbabwe teach all subjects in the curriculum. Some of the lecturers were specialist mathematicians, the majority though taught mainly other subjects. Table 1 sets out the responses to these non-specialists when asked to consider their teaching of mathematics in the context of their own subject area.

Both groups of teachers commented positively about coming to teach mathematics from the stance of a non-specialist mathematician. The Zimbabwean group in particular can be seen to offset interest in learners, wide general experience of teaching, a range of contexts from which to draw examples and the increased confidence that comes from maturity, against possible lack of knowledge, or poor experience themselves as learners. The group of retrained teachers were emphatic that study of mathematics itself re-kindled interest in teaching at a mid-stage of their careers.

The theme of ALM5 was 'Maths as part of lifelong learning'. This study will explore teachers as lifelong learners of mathematics. The purpose of project is to begin to compile a portfolio of circumstances when mathematics is taught and learned successfully, from the perspectives of both teachers and learners. Of particular interest are the perspectives brought by enthusiastic non-specialist teachers of mathematics, especially those teaching in courses such as Engineering or Psychology, and the research

* Although this is not a requirement for all degree programmes everywhere.

questions are framed to probe how these teachers integrate their own teaching to their learning of mathematics.

A baseline survey will establish who teaches mathematics to undergraduates in the university on which courses it is required, and how it is provided. Then the project will investigate what draws non-specialist mathematicians into this domain. Are non-specialist teachers be characterized in any way, for example by their enthusiasm for teaching per se, or their attitude to mathematics, or indeed by their views as to what mathematics actually is? Do non-specialist teachers of mathematics have noteworthy experiences of learning mathematics? Are non-specialist mathematics teachers particularly aware of the difficulties faced by learners? Have they had to adapt to changes in career direction?

How do teachers of mathematics describe successful teaching experience? Is successful teaching experience: defined by learning dependent on the nature of the mathematical ideas to be taught; dependent upon the teacher's ability to choose appropriate problems; determined through opportunities for verbalizing between teacher and learners; dependent on the teacher being able to choose appropriate and meaningful context and purpose for the mathematical activity; dependent on the teachers recognition of learners difficulties and their willingness and/or confidence to engage in mathematical discussion about these; connected with initial recognition by teacher or learner of shared culture/gender/ethnicity?

To what extent are difficulties in teaching mathematics related to pragmatic considerations such as the time available to teach it in, the need to 'cover' a particular syllabus, size of teaching group, etc.; related to previous poor experience of teaching; related to previous
poor experience of learning mathematics on the part of the teacher; related to insufficient mathematical knowledge or skill; related to insufficient knowledge of the context within which the mathematics is required or to be applied; related to insecurity in pedagogy, for instance teaching 'mixed ability groups', or inadequacy of curriculum resources?

The project field work is scheduled to be conducted during the academic year 1998-9, and I hope to report again to ALM as the work progresses.

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Table 1: Responses of college lecturers considering the teaching of mathematics in the context of their own subject.

Domain	Barriers to teaching mathematics	Strengths with respect to teaching mathematics
Mathematical knowledge	Insufficient maths skills; technical jargon; poor assimilation of formulas; poor at calculations; poor methodology; slowness at solving problems; statistics.	Good knowledge of general methods; plenty of contextual references from which to draw real examples, e.g. practical skills, e.g. economics, home economics, budgeting; agricultural projects; population studies; maths in real life; estimation: time, distance, speed; counting money, livestock.
Perceptions of mathematics as a discipline in school	Lack of interest; fear of figures, symbols and formulae; semantics.	basic maths skills; wide experience of seeing maths teaching; supervision of maths lessons; monitoring of projects; interaction with teachers of maths; own children's homework.
Commitment to their own subject	Pressure of exams; avoid teaching sections of the syllabus.	basic teaching skills; interest in children; expressive language for comparisons and quantification; ordinary conversation; free access to schools; collaboration with maths teachers especially in geography; opportunities for re-training.
Previous experience of mathematics learning	Bad experiences in school e.g. failure; improper use of terms; attitudes of maths teachers; inability to reason mathematically; failure to work out problems in maths	
Confidence in personal suitability	Negative attitudes; less adaptable because of age; lack of relevant training; far removed from the classroom; less qualified; fear of being challenged by more knowledgeable students.	Resourceful and experienced individuals; maths teachers attitudes can be taken as a challenge; good background on which to build; confident when maths demystified.

Source: Teachers' College Workshop, Zimbabwe, February 1997.