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A. G. Shannon  
*NSW Institute of Technology*

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# Mathematics Education, English Technological Universities and Variety of Entry into the Teaching Profession

*by A.G. Shannon*

*NSW Institute of Technology*

The purpose of this paper is to raise the issue of genuine variety of entry into the teaching profession in Australia. The author's interest in mathematics and technological institutions has been used to focus the discussion on specific features, but his experience as a member of the Course Assessment Committee of the NSW Board of Teacher Education has made him aware of wider implications beyond the features peculiar to mathematics.

Mathematics education itself is a term which can include the teaching of mathematics, studies about the learning of mathematics, and the preparation of mathematics teachers. The various aspects of mathematics education are interwoven, and whether technological universities have anything distinctive to offer depends to what extent they have taken seriously their role of being "equal but different" in terms of course content and structure, and of course in so far as that political phrase has any educational meaning.

History, geography and politics can force a role upon an institution in isolation from any discussion of the educational issues involved, and many of these issues apply to colleges of advanced education in general. An overseas visitor can sometimes see things which those with their noses to the grindstone might miss, even allowing for the oversimplifications likely to be made by one who is not personally involved. It is an appropriate time for such an exercise when institutions both in England and Australia are being forced to reassess their activities.

The preparation of mathematics teachers will form the unifying thread through this paper. Readers might compare the situation in their own fields of study and in their own institutions to see what extent they are contributing to a genuine choice.

The preparation of mathematics teachers is a responsibility of the whole mathematical community, a point of view which has been forcefully expressed within the Canadian context by the main professional associations with interests in mathematics (Beltzner et al, 1976). However, the preparation of teachers is a responsibility of the whole educational community, since what educators and academics do, affects teacher education either directly or indirectly. It is thus arguable that this journal is an appropriate medium to air these views.

The preparation of mathematics teachers in a university cannot be isolated from the general structure and content of other courses. Nor should it be if those who contend that prospective teachers should mix with fellow students in a variety of disciplines. Of course a mathematics department might have no commitment to the preparation of

mathematics teachers because it sees such a role as inappropriate. When questioned about this, one professor to whom I spoke thumped the table and said: "We do not want anything to do with education!"

McLone (1973) notes three causes of disillusionment to be found amongst many mathematics graduates in general: the job uses little of the course done in the degree; the level of mathematics required in the job is often well below degree standard; the qualities and abilities needed of him are such that the average graduate often lacks. That these apply in varying degree to teachers of mathematics would be fairly obvious.

McLone saw in these causes two different aspects related to the demand for mathematics. One is a question of more harmony between education received and employment offered. The other is the concern of universities to organise their courses to provide an education satisfying for the student, to educate *through* as well as *in* mathematics, because the personality and general ability and attitudes of the graduate remain more critical in employment selection than class and content of degree.

### ENGLISH TECHNOLOGICAL UNIVERSITIES

Counterparts of the French Ecole Polytechnique (founded in 1794) and of the Ecole des Arts et Metiers were instituted in Regent Street and Trafalgar Square in London in 1840, but neither survived.

The commissioners of the 1851 exhibition offered to build a technical university at South Kensington, an offer conditional on the government's acceptance of responsibility for maintenance. The government's unwillingness was overcome by the city guilds' offer of land and the city companies' provision of money so that a junior technical college was built at Finsbury in 1881 and an applied science college at South Kensington in 1884. These became the Imperial College of Science and Technology in 1907.

In the meantime the old Regent Street Polytechnic had been revived, not as a technical university, but as an agency for the moral improvement of the working classes! Its success encouraged the founding of others in the early 1880's, and the Technical Instruction Act of 1889 enabled the London polytechnics to become models, not just for other parts of England, but for other English speaking countries.

The development of some technical institutions in other parts of England will be referred to later. Some of these began to emerge in the 1890's. By 1945 they had developed to the stage where the Percy Report was able to recommend that a strictly limited number of technical colleges should be allowed to offer technological courses of a standard comparable with that of university degree courses. The reason was to remedy the failure to secure the fullest possible application of science to industry.

Growing postwar pressures for scientists and technologists and various recommendations of advisory councils on scientific policies lead to the reclassifying of some institutions as Colleges of Advanced Technology in the mid 1950's, and then as technological universities in the mid 1960's.

Only one of these, Loughborough, still calls itself a university of technology; some see this as significant. At a 1977 conference arranged by the Institution of Mechanical Engineers in London, Mr Ronald F. Marshall of the British Aircraft Corporation had this to say: "the colleges of advanced technology were the right answer, both in form and content, for our industrial needs. Moreover, they were seen to work. But they were

never allowed to establish themselves. They were the solution to our problem and we threw the solution away" (Surrudge, 1977). Those Australian Colleges of Advanced Education which see themselves as universities might well ponder this.

### Course Structure

The English technological universities, to be fair, have grasped the opportunity for distinctive approaches to the structure of their mathematics courses through their contacts with industry, especially in thick sandwich courses. The state of Australian industry and the relatively few mathematicians in it make sandwich courses in mathematics a doubtful proposition in Australia.

One can discern in some institutions an unstated view of mathematics education itself as an application of mathematics. This is a position that would probably be appreciated by many teachers of school mathematics who might in fact regard it as one of the more difficult and less successful applications. However, the focus here is on the BTech and BSc programmes rather than on the emerging BEd courses which are being developed or inherited, and in which students are sometimes regarded mathematically as second class citizens.

The description here is only a brief outline of the structure of mathematics courses (with particular reference to the preparation of mathematics teachers) in those technological institutions which became universities in 1966 and 1967. These places form a recognisable bunch, so that this survey omits places like Chelsea College, University of London, which started life in the nineteenth century as South West London Polytechnic, and became in turn Chelsea Polytechnic, Chelsea C.A.T., and then a recognised school of London University. Chelsea is mentioned because it has a very obvious involvement in all facets of mathematics education, particularly with its Centre for Science Education and its participation in the Nuffield Foundation and Schools Council Projects. Chelsea, along with University College, London, and Surrey University is involved in a national development programme in computer assisted learning. Why this is worth noting is that such approaches in mathematics are conspicuous by their absence in general in the technological universities, and yet one would have thought that mathematics and technological institutions would provide a nice blend for developments in both computer-assisted and computer-managed learning.

### UK TECHNOLOGICAL UNIVERSITIES

#### *The University of Aston in Birmingham*

Aston had originally been founded in 1895 as the Birmingham Municipal Technical School. Subsequently, it became the Central Technical College in 1927, the Birmingham College of Technology in 1951 and a CAT in 1957.

It offers a combined honours BSc in mathematics and education. The education component is offered by a department of education which has shown initiative in the development of the Aston Educational Enquiry Monographs under the general editorship of Professor Richard Whitfield, a former chemist. This point is made because there is a fair amount of activity in areas other than mathematics in some of these universities, in case the impression is given that they are not involved in educational research. The education component of the Aston BSc has as its goal the provision of "a basic study of man in educative society". An option in the foundations of educational

enquiry can be done in any combined honours programme. Although mathematics students can do three years of education, they still have to do a professional teacher training year since the education courses do not require teaching practice.

In a sense these students are not handicapped in the time taken to join the rat-race, because the BSc in mathematics is also offered as a four year thick sandwich course. In the latter, the third year is spent in industry. As the prospective mathematics teacher is not involved in this, he could be missing out on a distinctive feature of a technological university, unless he can get the financial support to spend the extra year in industry and to do the post-graduate certificate in education. Sandwich or co-operative programmes are a special feature of the technological universities, though not unique to them of course.

It is worth noting the distinction between two types of sandwich programme: "thick", as described above, and "thin" where students spend on average two terms in the university and about six months in industry in at least two years of the course. These courses are sometimes further qualified as "fanning", wherein optional specialised subjects are added to a common core. British students are generally more advanced mathematically at the end of their first year, and hence of potentially more use (mathematically) to industry.

Aston, like some of the other technological universities, offers an MSc in educational studies, but as they are not specifically designed for mathematics teachers, they will not be referred to.

#### *The University of Bath*

This started life as the Bristol Trade School in 1856. Between then and 1971 when it dropped the word "technology" from its title, its changes of name were Merchant Venturers' Technical College (1894), C.A.T. (1960) and Bath University of Technology (1966). These details are not trivial as they emphasise the origins and traditions of these universities of technology.

The department of education at Bath is a designated centre for the training of teachers of technology and science. It also provides the university's educational media service. What is more to the point, it offers a sandwich-type degree plus a teachers' certificate in collaboration with the departments of mathematics, sociology and physics.

Mathematics and education share the same building, and as each student has a personal tutor and a course tutor, there can be quite an amount of guidance and selection of prospective mathematics teachers.

There is a common foundation year for all mathematics students, and those who are interested in teaching are interviewed during this year. In their second year, these students have four weeks teaching practice in September at the start of the school year and before the commencement of the university year. They then do one course in education during that year. In their third year, they spend one term in industry and two in education. Their final year of academic study is meant to round off their total preparation. This is an example of a technological university which is offering something distinctive in the preparation of mathematics teachers.

#### *Bradford University*

This was previously the Bradford Institute of Technology (1957). An honours BSc in mathematical sciences is said in the handbook to be "particularly suitable for those intending to enter the teaching profession", but it does not say why. A perusal of the courses offered does not answer the question either. However this technological institution is well served by a particularly active Department of Research in Education which has included in recent years such well known educationists as Ruth Beard, Louis Cohen, Alan Smithers and Colin Flood-Page. Bradford also offers a BTech which differs from the BSc in that it requires a sandwich programme. This distinction is followed in several institutions. Bradford is now taking an interest in a scheme called "Polymaths" which started in Lanchester Polytechnic at Coventry, (though that is not the source of its name).

Polymaths was originally intended for mature students to give them a second chance in mathematics (James, 1977). The scheme itself is a model teaching and learning programme which has been validated in many Colleges of Education and Polytechnics, and has now been accepted as an alternative to a GCE 'A' level by many tertiary institutions. It is ideally suited as a preparation and support for a programme such as that of Bradford which hopes to attract prospective mathematics teachers but cannot mount courses which cater for them. The emphasis on modelling in the content of "Polymaths" and the strategies for learning in its development are an ideal blend for the prospective mathematics teachers.

In fact some English local authorities now recognise the completion of the Polymaths course for promotion and salary increment purpose. There are no formal examinations but the assessment is thorough and constructive and on completion of the course the student can receive a certificate validated by the Institute of Mathematics and Its Applications which is a sponsor of the scheme. At least one teachers' college in Sydney is also exploring the possibility of this course for primary teachers because of its comprehensive mathematical content.

#### *Brunel University*

Prior to 1966 Brunel had been a regional college of technology (1957) which was "upgraded" to CAT status in 1962.

Brunel has a very active education department, which besides being a TV/AV centre and offering an MPhil in education, contributes to the professional training of Brunel staff. In this it is like Surrey University's Institute of Technology. Like Aston to some extent, it offers a complementary studies programme for all students: this is an opportunity for a student to study voluntarily at least one subject outside the major field of study.

One might also see Brunel's Further Education Monographs as a proper role for a technological institution, since it is likely to have the resources and experience for such studies. Of interest in the current controversy about numeracy is the study of the difficulties in mathematics of craft and technician students by Brunel's Ruth Rees (1973). This illustrates the point made earlier: how a technological institution can utilise its technical expertise, interests and other human and material resources to provide a service which no other body can perhaps provide as efficiently. It raises issues of co-operation, competition and community relations to which we shall return. (In a somewhat similar vein is the illustrated guide to mathematics for engineering produced

by the Shell Centre for Mathematical Education (1977) at Nottingham University. Nottingham is not a technological university of course, but it is worth noting that Shell sees mathematics education as worth supporting there and elsewhere. Perhaps this is an argument in favour of involvement in mathematics education in its widest meaning by technological universities, on the assumption that they have something distinctive to offer?).

The education department at Brunel also offers degrees in combination with mathematics and physics. In first year there is no systematic study of education, but there are occasional informal talks and seminars to prepare for later educational studies. As well as mathematics in their second and third years, the prospective mathematics teachers also study methods of teaching secondary mathematics, educational psychology, sociology and technology, as well as curriculum development and assessment theory. The last is also studied in their fourth and final year together with mathematical education.

At some stage two "industrial periods" of practical work in education are required. These normally involve practical teaching experience in a school or other educational institution, but in certain cases it is possible to substitute some other form of work in education. At these times their fellow mathematics students are in industry. These students are classified as industry based or university based. In the latter case their firm is chosen by the university. All students have both an academic and an industrial tutor.

#### *City University*

This was previously Northampton CAT (1957) and before that it had been the Northampton Institute (1891). It has no department of education, but there is a centre for educational technology which is now involved with Surrey University and Hatfield Polytechnic in a Postgraduate Diploma in Teaching and Learning under the direction of Dr John Gilbert of Surrey. City offers a sandwich degree in mathematics in which it is possible to do some psychology or sociology, but there is no direct involvement with teacher preparation.

#### *Loughborough University of Technology*

This has been through the metamorphoses of being Loughborough College of Technology (1952), Leicestershire Technical Institute (1908), and in between, Loughborough College (1918). Separate colleges were formed from it between the World Wars. Of these, Loughborough College of Education, which offers a BEd for mathematics teachers, is rejoining it.

There is a Chair in Mathematics Education held by Avi Bajpai, and an honours BSc and Certificate in Education in mathematics and education. In joint honours courses there is close integration of the two subjects, especially with references to applications in science and technology. In their third year those who plan to be mathematics teachers follow individual studies in the first term, and the next two terms are spent in teaching practice.

The structure of the degree is intended to be such that students can enter an alternative career on completion of the course should they wish to defer their entry into teaching (in which respect it is unlike the BEd).

Other general features of interest about Loughborough are that 90 percent of undergraduates are in residence and that several departments of the university have

appointed an industrial professor. Such a person is appointed for a period of three years and provides a valuable link between the university and industry. He visits the department regularly and undertakes research in an area of specialisation that the department concerned would not normally be able to pursue.

C.A.M.E.T. (Centre for the Advancement of Mathematical Education in Technology) is at Loughborough and it provides short courses for industrial establishments and educational institutions. It has produced a number of programmed learning texts for engineering mathematics, and it develops audio-visual aids in general. It founded the *International Journal of Mathematical Education in Science and Technology* which exists to provide a medium in which a wide range of experience in mathematical education can be presented, assimilated and eventually adapted to everyday needs in schools, colleges, polytechnics and universities, as well as in industry and commerce. CAMET and the journal are distinctive initiatives to mathematics education from a technological university.

(In view of changing patterns of study leave in Australian tertiary institutions, it might be of more than passing interest for readers to be aware that it is possible, under certain circumstances, for candidates to pursue higher degrees at Loughborough almost entirely as an external student. The present writer is an external supervisor for one such student in Sydney).

#### *University of Salford*

Salford received its charter in 1967 after 65 years as the Royal Technical Institute and six years as a CAT. It has no education department and provides no specific courses for intending mathematics teachers.

From the viewpoint of mathematics education in general, its mathematics courses attempt to grapple with modern applications, and it has an audiovisual media unit which is concerned with research and educational methodology. A feature of interest of this unit is its involvement with the Northern Universities Working Party for Co-operation in Educational Technology, which exists to ensure greater co-operation with regard to the exchange of information and the discussion of issues such as copyright and the compatibility of equipment. Apropos the proper contribution to higher education by technological institutions, the educational technology role seems to be an area which has been taken seriously, though its effectiveness is hard to evaluate except at a superficial level. Obviously it is not enough for such aids merely to exist.

#### *University of Surrey*

This was founded in 1891 as Battersea Polytechnic, and through the Institute of Educational Technology, a constituent department of the university, it has projected an image of effectiveness in this area. The IET is headed by a Professor of Science Education, Lewis Elton, who was formerly the Professor of Physics there.

Surrey offers a BSc in mathematics, and a BSc in technological mathematics (with an industrial training year), but nothing specifically for the pre-service education of mathematics teachers.

#### *U.K. — AUSTRALIA COMPARISONS*

It was mentioned earlier that the industrial scene in Australia precludes any direct imitation of the British system, even if that were desirable. The British educational

scene is more complex too. At the university level we find at least four categories: Oxbridge, the Redbrick, the technological, and the other new universities (such as Keele and the Open). Then there are Polytechnics and Colleges of Higher Education. There are also numerous Colleges of Education and Colleges of Technology which are amalgamating at an alarming rate, some with the foregoing, others with Colleges of Further Education. (A separate, but disconcerting, issue is the redundancy of many experienced lecturers).

The accompanying table summarises the main features of the British technological universities in relation to the preparation of mathematics teachers within the British context. Bath and Loughborough contribute most to genuine variety of entry for mathematics teachers into the teaching profession, because such students automatically experience periods in industry. This takes maximum advantages of the special resources of technological institutions.

Comparison of British Technological Universities on basis of undergraduate mathematics teacher education

	Aston	Bath	Bradford	Brunel	City	Loughborough	Salford	Surrey
Maths. Teacher Ed. specifically catered for	✓	✓	x	✓	x	✓	x	x
Industrial component possible for prospective teachers	x	✓	✓	✓	✓	✓	x	✓
Teacher education integrated	x	✓	x	✓	x	✓	x	x
Teacher education at end	✓	x	x	x	x	x	x	x
Relative merit for maths teachers on bases of catering for needs and variety of experience	2	1	3	2	3	1	4	4

These two universities, along with Aston and Brunel, offer most guidance if aspects were to be adapted to Australian conditions.

No suggestion is being made that this should be the only, or even the preponderant, mode of educating mathematics teachers. Nevertheless, it has become clear from the present courses in aspects of Operations Research, Statistics and Mathematical Modelling in B.Ed. programmes in Australian C.A.E.'s, that there is a growing recognition of the need for some familiarity with these areas. Nevertheless, the resources available for, and the time spent on, these courses is generally insufficient to get beyond the recognition stage.

If there are to be mathematics teachers with what one might call "majors" in industrial mathematics, then such people could receive their mathematical education in those C.A.E.'s which currently prepare mathematicians for industry. The education components can be integrated readily enough for those few students who might be involved in such schemes.

There are, of course, at least three suppositions to all this. There is the assumption that such CAEs would be willing to be involved in some aspects of teacher education, an area regarded at the "kiss of death" by some. At present the only Australian technological CAEs with a commitment to teacher education are the Tasmanian and Ballarat and Bendigo CAEs, Darling Downs and Capricornia IAEs, and Western Australian Institute of Technology.

There is the supposition that such variety of entry would be a good thing for the educational profession. Besides being the "spice of life", I believe variety in the sense I am suggesting would enable more appropriate mathematics courses to be developed for secondary schools especially, appropriate that is in terms of genuine interest, ease of co-ordination with other studies, and the mathematical maturity of the youngsters.

Furthermore, I believe there would be a greater application of industrial mathematics to the theory of education, particularly educational administration.

Another assumption is that CAE academics now involved in the preparation of mathematics teachers would be happy to lose some of their EFTS!

I believe the key to this would be co-operation, and that is the biggest assumption of all.

Most of us realise the difficulty in getting co-operation within an institution, let alone between institutions. Yet it is achieved with varying success in many parts of the USA, and there is no educational reason it could not be implemented in this country. Circumstances are forcing it on some institutions in the UK, and I believe that it will be necessary in Australia if negative competition in the sense of a zero-sum two person game is to be avoided in the future. (I am not referring to amalgamation).

In the meantime until the dreamtime, the Polymaths programme from Britain is a realistic foundation for final year BEd courses on mathematical modelling which get past the hand-waving stage (though there is a place for that in the recognition and formulation of models). The Polymaths course has 125 class contact hours made up of fifty 2½ hour sessions, which involve mini-lectures, group discussions, and problem sessions with continuous and periodic assessment done by the student out of class. The course covers these five sections: logic and number laws; functions; sets, relations and structure; calculus; computing. The books assume the students know next to nothing and yet they are written for adults: an achievement in itself.

Some of those involved in the Polymaths scheme have received a grant to spend time in 1969 in the preparation of substantial case studies for the mathematical modelling courses.

#### CONCLUDING REMARKS

The mathematics degrees at the English technological universities offer a real alternative in terms of their structure. In general, it is debatable to what extent they do so in terms of content and teaching methods. For instance, more use could probably be made of teaching through projects as is common in their engineering departments. An important gain in this approach is the improvement of verbal and written communication, which are areas where mathematicians are said to be weak and is regarded as a reason relatively few mathematicians are promoted into management in industry (McLone, 1973). Sullivan (1977) has developed the project form of assessment in a form suitable for most levels. It can also be an important component in the development of the abilities to recognise and formulate problems.

In some of these universities there has been a commendable concern to develop courses for the many who will need it as a tool rather than concentrate on the few who will go on for graduate work in mathematics, but there is still some confusion about the preparation of the industrial mathematician or the user of mathematics in general (the "player" rather than the "gentleman" in the cricketer analogy of Elton (1971.))

Elsewhere the present author (1973) has outlined more fully the problems peculiar to the preparation of mathematicians for industry.

Other institutions are already providing an alternative means of entry into the teaching profession. One of the most promising is at London's Polytechnic of the South Bank in co-operation with Avery Hill College in South East London. In this combined BSc-Certificate in Education programme, the mathematics students who intend to become teachers spend five weeks at the end of a common first year in schools where they can observe and obtain some teaching practice. If this puts them off they can switch without a break in their studies back to the business side of the sandwich BSc in mathematics and computing. Those who choose education will spend the first six months of their third year in industrial training to get valuable experience of the "real" world, according to Dr David Fyfe, the course director. This is one of a number of interesting initiatives undertaken by polytechnics which would be of interest to mathematicians. Oxford and Brighton Polytechnics are others with programmes which face their role in the community squarely and realistically.

Nearer to home, one might question what genuine variety of entry (rather than depth of preparation) there is for the mathematics teaching profession in Australia, whether there should be variety in initial teaching preparation, and what responsibility mathematicians in general have for this.

Academics with interests in the preparation of teachers in other disciplines can gauge the pertinence of the foregoing for their own students. In this respect, readers might like to have their attention drawn to another article in which the author (1978) has delineated a recent British scheme in which serving teachers from any discipline can spend periods in industry which are potentially of value to industry and teachers, and through them to their pupils.

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