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TEACHER EDUCATION IN TRANSITION - A COMMENTARY ON POSTGRADUATE SCIENCE TEACHER TRAINING IN ENGLAND

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INTRODUCTION

The radical reforms of recent years have affected all parts of the educational system in England. This paper discusses science teacher education and focuses on changes in teacher training programmes designed to equip teachers for the national curriculum and for work in the climate of greater accountability that now exists. Though the pressure for these changes is domestic it is suggested that the issues are of general significance.

The author has been involved in science teacher education at the Institute for some 25 years and has shared in the developments outlined in this paper.

Teacher education in England is currently subject to several pressures which are leading to significant changes in practice. Though these changes are stimulated by national factors, many of the underlying issues are neither new nor parochially national and will be recognised as having relevance in other countries.

The central issue centres on who should train the new teachers. Government policy favours teachers being trained 'on the job' in schools by teachers with education departments of higher education playing a much smaller role than they do at present. For science specialists a second concern is how to ensure that teachers have a sufficiently broad science capability to work confidently with the national curriculum. Beside these two pressing demands a contemporary challenge is how to harness the rich experience of the many recruits to teaching who are attempting to begin a second career.

We shall briefly look at each of these issues but it should be borne in mind that in practice they interact in many complex ways and the list is not a hierarchical one.

1. Moulding and personal development

Schools require teachers who will maintain standards. These standards are conceived in terms of behaviour, values and academic

performance. A course of teacher training is expected to nurture a professional disposition towards these notions of standards so as to provide schools with a supply of teachers who will conform sufficiently within established norms. These factors all suggest that part of teacher education should be a shaping or moulding process which identifies the expected characteristics of 'the teacher' and nurtures them. In contrast to this there is a concern to develop the potential of new entrants to the profession and to capitalise on the experience and often the maturity of those who are coming into teaching. Undue emphasis on the moulding function is likely to damage the encouragement of individuality and self-confidence of some of those whose life experience means that they have so much to bring to schools. Effective resolution of these two dimensions of teacher education is a contemporary theme that is especially important in the light of the 1988 Education Reform Act which both introduces a measure of prescription in the curriculum and promotes competition between neighbouring schools. Therefore teachers will need to be confident and highly professional in the climate of accountability in which they will work.

2. Scientific specialism and breadth

Students entering teacher education for the science PGCE course are all graduates in some aspect of science. Their qualifications are extremely varied. While the majority have majored in areas that would generally be classified as biology, chemistry or physics, many have degrees in newer and applied studies such as environmental science or agricultural botany. Students with these degrees may lack a general background spanning biology, chemistry and physics. This presents problems to these prospective teachers now that there is a national science curriculum that entitles every pupil to a 'broad and balanced' science education. In many schools science courses to the age of sixteen treat science as a unified study and schools seek teachers with the knowledge and

confidence to teach this broad curriculum. Therefore teacher education courses have to attempt to address the issue of breadth in science for graduates whose own science education has been over specialised.

3. University and school partnership

For a decade there has been an increasing emphasis in teacher education on the contribution of schools to the formation process. This has occurred as educational theory taught as a college-based component has declined in importance and has been substantially replaced by consideration of issues thought to be important within schools. Accompanying this change there has been a growth in the role that school teachers have in the postgraduate course. They are involved first in the selection of applicants for admission to teacher training, share in the planning of courses and make some contribution to college-based teaching sessions as well as supervising students in school. The education department at Oxford has done pioneering work in this direction by training teachers to be mentors for student teachers (Benton 1990). This trend is now being pressed further by Her Majesty's Government who wish to ensure that all teacher education is grounded in practical school experience and not rooted in what some politicians regard as spurious educational theories. Therefore teacher education at the London Institute is presently in transition towards becoming what is known as an area-based programme which will make a further swing in the balance between college and school in the training process. The plans discussed here will achieve an approximately equal partnership between the university and participating schools in the teacher training enterprise. Whether this shift in emphasis will satisfy Government requirements remains to be seen but a consultation document submitted to universities, colleges and schools speaks of a 80/20 per cent split in time for student teachers between school and education department respectively.

The response of higher education to these more radical proposals has been consistent. Teacher educators share the belief that schools and their teachers should play a more significant role in the training and induction of new teachers. To this end the notion of partnership is welcomed. At the same time it is argued there is a dimension of

teacher education that is best informed by research and a breadth of view that transcends a single school or local group of schools. This function can best be served by higher education which can also carry the responsibility for overall quality control. Therefore, while higher education accepts equality of partnership it rejects proposals that would give the dominant position in that partnership to schools.

The area-based scheme which is discussed in this paper is designed to achieve a mutually beneficial school/university partnership. Though the account which follows relates to science education other curriculum subjects are preparing similar plans.

Context for Science Education

The 1988 Education Reform Act gave science a secure and prime place in the national curriculum as a core subject. The Curriculum Working Group (DES 1988) set up to advise on attainment targets and programmes of study for science within the framework of the national curriculum stated:

The science we want to promote should be accessible to all pupils. It should be broad enough to cover the economic, social, personal and ethical implications of science, balanced enough to reflect the inter-relatedness of physics, chemistry and biology, relevant to pupils' everyday experience and today's world; to girls as well as boys and to pupils of all social, cultural and ethnic backgrounds.

Delivery of such a curriculum and achievement of the attainment goals which have been specified will depend substantially on the quality and quantity of science teachers. All those involved in the teacher education process have important roles in equipping teachers during their initial training with the skills which schools will require, for as Her Majesty's Inspectors (1987) stated in their survey of initial training of teachers, good training sets out to lay firm foundations for a lifetime as a teacher. Further, they say of initial training:

The student's experience in this formative period will go far towards shaping his or her attitudes and understandings; it should provide a body of knowledge and a range of skills that will meet immediate professional needs; and it should encourage an open mind and a desire to go on learning and developing.

The PGCE course assumes the student's competence in the teaching subject commensurate with that of being a graduate. Yet, as we have noted, this knowledge is often highly specialised and ill-matched to the school curriculum. Furthermore undergraduate science courses are not geared to the development of communication skills and study skills are more often assumed than taught. Learning scientific facts, theories and mastery of practical, investigational skills are at a premium. By contrast the PGCE programme is much concerned with the development of the person and interpersonal skills. It is in this context that the new teacher's knowledge and understanding of science has to be reappraised. Consideration of Appendix 1 which gives a set of objectives for the science curriculum course in which the author is engaged will indicate directions in which the student's thinking is focused.

The Postgraduate Certificate Year

Minimum requirements for all teacher education courses are now laid down by the government sponsored Council for the Accreditation of Teacher Education (CATE 1985 and 1986). The specification includes duration of courses, minimum entry qualifications for student teachers and some direction on course content as well as prescription of a minimum time to be spent in schools by each student. CATE further requires that all who are engaged in supervision of students during school practice have 'recent and relevant' experience of classroom teaching. Developments at the London Institute necessarily meet these requirements and the decision to move to a more school-based programme anticipated the announcement by the Secretary of State for Education that all secondary teacher training must move in this direction. Subsequently the potential and necessary conditions for area-based training were set out by Her Majesty's inspectors in a paper released early in 1992 (HMI 1991).

The PGCE course begins in September with two weeks' preliminary school experience. Normally a student spends two weeks attached to a primary school when the emphasis is upon observation of both teachers and pupils, upon understanding the goals and methods of the school rather than on undertaking teaching assignments. This school experience is not supervised by Institute staff but study guidelines are sent to students in advance and there are follow-up sessions in the early days of the course during October.

The PGCE year occupies 36 weeks and a minimum of 15 of these must be spent in school. Two teaching practice blocks make up most of these 15 weeks. The first occupies four days a week in the second half of the first term but the students return to the Institute on Fridays to engage in analysis and reflection on their school experiences and to undertake further study and preparation for the next week's teaching. Teaching practice is completed in the second term with seven weeks full-time in schools in the period leading up to Easter.

Additional school experience is gained by sessions in school as integral parts of the PGCE course programme and by visits to enable students to see a wide variety of educational establishments.

Teaching practice apart, the typical week sees the student involved with science teaching and science curriculum issues on two days. This constitutes what used to be known as the 'methods course' and currently requires students to work in college for rather more than half of the two days a week with the remainder spent in tutor groups in specially selected schools. Early in the course these school-based days have a particularly high priority with a view to achieving the objectives listed in Appendix 2.

Also one day each week is given to a general education course. This is an issue-focused programme, far removed from the traditional systematic lectures on psychology, philosophy and sociology of education. A further day is devoted to a chosen study course often focusing on a whole school policy issue such as special needs or a cross-curriculum topic including museum studies or information technology. This leaves students with one day in which to manage their own reading and course work.

School-based Training - The Challenge

The transition to an area-based scheme will effect a major change in the place and teaching of the education and special study courses. These elements in future will be taught to a multi-disciplinary group of students in a school, or consortium of schools, and designated teachers will carry a substantial responsibility for the teaching in partnership with an Institute tutor. In the short term at least curriculum work in science will continue to be largely Institute based. Thus under this system students will spend most of their course in school.

This change is one strongly advocated by government ministers who urge the need for teachers to 'learn on the job'. They proclaim that this will enable beginning teachers to become effective in class control, unencumbered by the 'dogma of educational theory' and with their minds concentrated on practical issues pertinent to teaching their subject. It is also widely acknowledged that the best way to learn to teach in a challenging inner city situation is to be specifically trained in that context. The area-based programme will mark a new degree of partnership with London schools and high priority will be given to appropriate delivery of the national curriculum to these pupils, many of who are bilingual, coming from homes where the language spoken is not English. Approaching the national curriculum as an 'entitlement curriculum' for all pupils takes on a particular significance in these circumstances.

The area-based scheme will be demanding on schools. Many of these schools have suffered staff instability and shortages yet for the scheme to be successful it will be necessary for experienced teachers to be diverted from classroom teaching to working with students. On the credit side it is expected that the receiving school will have several students for much of the year and that as they begin to identify closely with the school and develop their skills they should be able to make a significant contribution to school life. This in turn may ease some of the recruitment problems that inner city schools have experienced in the past.

A successful outcome of the area-based programme will also require teachers and college tutors to have shared goals. This has always been a desirable ingredient of teacher education but a dimension that frequently left something to be desired. Significantly the term 'teacher training' is still widely used and it immediately highlights a sensitive issue. Training is suggestive of drill, routine and discipline, with a 'right' way of doing things. Training may be interpreted as a moulding process designed to produce teachers who will conform, as nearly as possible, to an idealised prototype and who will therefore slot neatly into the school as it is. This would be an understandable goal for the teacher mentor but many tutors in University Departments of Education prefer to think in terms of teacher education giving emphasis to the achievement of personal discovery, development of individual skills and flair and the production of teachers ready to teach in schools as they are but also capable of contributing to progressive evolution of schooling.

Helping new recruits to find an individual, personal teaching identity but one which encompasses collaboration with colleagues within the institutional setting of a school necessarily involves teachers in school and tutors in balancing elements of habit-forming training with educative exploration and reflection in order to nurture the beginner's teaching style. Achieving this balance is a persistent challenge in teacher education and a recent innovation at the London Institute towards realisation of this goal is the introduction of a system of personal profiling. Students are required to keep a personal diary in which they record observations and reflections on their experiences. Tutors also set frequent small tasks which further encourage critical analysis of issues and policies. Formal course assessment work makes similar demands but at greater length and with more reliance on educational literature but not to the exclusion of personal judgement. All these elements contribute to a student's portfolio which is summarized in a profile statement of courses completed and teaching undertaken together with a statement of personal strengths and achievements, especially those evident on teaching practice. All pieces of written work, with the exception of confidential diary entries, are discussed with tutors. Additionally the student's teaching is monitored and reported upon in writing by both tutor and supervising teacher. Students are expected to write a short evaluation on each of their lessons and to add their own written comments on reports made upon their teaching by teachers and tutors. Thus students are encouraged from the outset to evaluate themselves and to engage in dialogue about their successes and failures. Formative assessment of this kind will, it is hoped, not only contribute to their immediate development of teaching skills and professional awareness but also prepare them for the scheme of teacher appraisal that is beginning to be introduced as a mandatory process in English schools and for the new degree of accountability which is one consequence of recent educational reforms.

Recruits to Science Teaching

Historically new recruits to science teaching were young graduates in their mid-twenties who, after achieving three 'A' level passes with a strong scientific emphasis, followed a three year science degree course comprising a number of highly specialised modular courses. These course units involved many hours in laboratories, punctuated by intensive lectures when up-to-date

information was retained and when note-taking may have been the dominant student activity. The final undergraduate year probably featured an individual study which provided experience in personal application, research techniques and furthered specialist knowledge. Our typical science graduate may have experienced little group discussion in seminars and the choice of course modules was probably determined by such factors as personal interest, convenience or tutor personality but rarely by a conscious desire to achieve a balanced overview of science. Frequently the graduate recruit was equipped with packages of highly detailed knowledge and sophisticated practical skills pertinent to specific studies. Manipulation of mathematical data or chemical symbols may be more highly developed than verbal skills. A further year or two studying for a master's degree may have extended both the knowledge and practical skills but all in the direction of greater specialisation. Our potential science teacher probably has little knowledge of the history and philosophy of science and only a rudimentary understanding of the contribution which his or her chosen field has made to human culture. Likewise there may be little appreciation of its ramification into technology and the consequent impact on society.

Today graduates with this kind of background still come into teaching though they may have spent a year travelling or sampling a variety of jobs. To their numbers are added a substantial intake who have extended experience in employment and who may have become redundant or who have positively chosen a change of career. These entrants bring with them a vastly greater experience of life, of working practices and often the insights into childhood and perhaps adolescent behaviour borne of parenthood. Their science education usually bears many of the characteristics of the new graduate but may be enriched by relevant practical and technological experience or, alternatively, may have fallen into disuse and suffer from lack of up-to-date knowledge. While these people bring the perspective of greater experience their scientific knowledge usually carries the familiar stamp of over-specialisation for a profession which now requires the added quality of breadth. The presence of a good proportion of these students significantly enriches the student body and the tutor groups in which so much of the work and discussion occurs.

Breadth of scientific competence has to be faced head-on during the PGCE year. The new trainee teacher is often surprised, or even disturbed, to

discover that even in the field of science there is much further thinking and learning to be done. As we have already seen an important dimension of the PGCE course is to help balance and fill out the new teacher's overall scientific competence, but this has to be done without damage to the student's confidence in his or her scientific knowledge. As part of the course attention will be given to laboratory skills which will soon come under the scrutiny of children in whom safe, efficient procedures are to be nurtured. Also, reflection upon the nature of science will be provoked, leading to debate about process and content and continuing into discussion of the relationship between science, technology and society.

The Science Curriculum Course

Time is desperately short in which to begin to produce this breadth. Furthermore the needs of each individual are distinct. At the Institute our approach to this problem has been developed over a number of years and appears to give considerable satisfaction to the students and therefore the programme is planned to continue when the area-based scheme begins. Apart from block teaching practice about one day per week is given to a 'basic science' course. Each week a discrete topic is considered. Topics are always those that feature prominently in the national curriculum (see Appendix 3). Basic science days follow a similar pattern and all science graduates are involved together in the main sessions. First a tutor gives an introductory presentation which opens up some pedagogical issue especially pertinent to the topic. There follows two hours of laboratory activities which represent many of the practical tasks that feature in classes in most schools. These activities are often graded according to their suitability for pupils of different age and ability but the emphasis is upon the first three years of secondary school. Students are encouraged to select and work through those activities most necessary for them. Thus on the electricity topic students with minimal knowledge would be expected to master essential concepts required for teaching pupils up to the age of fourteen. Meanwhile graduates in physics might turn their attention in other directions. First they may work alongside a colleague who is trying to revise or learn the ideas for the first time and in doing so to gain insight into some of the conceptual difficulties and discover the language necessary to give explanations. Here it soon becomes clear that a biologist may not understand some rudimentary aspect of

electricity but nevertheless is quick to jump on a feeble explanation! Alternatively the physicist may elect to work with some unfamiliar or more advanced laboratory resources. The next week when diversity of life or senses may be the topic the biologists probably engage in peer teaching while physical science graduates grapple with materials unfamiliar to them. Always several members of science staff are deployed in the laboratories during these sessions and always tutors with different specialisms form the team so that there is an implicit message that it is not necessary to be highly specialised to teach national curriculum science especially up to the end of key stage 3, that is age 14. Team work by staff becomes evident and co-operative working by students is positively encouraged. Authenticity of school relevance of these sessions is added by the occasional participation of school teachers and by school visits where teaching these topics is observed and also shared by the students.

Basic science sessions pay considerable attention to pupils' learning and this is a major focus of school based days. Beginning teachers have to learn to relate science to children of different ages, abilities and aptitudes. Therefore, early in their course, students are placed in interactive situations with small groups of pupils, so that they can tune in to the children's language register, become aware of their scientific ideas and engage in dialogue. Observation of science teaching will be focused to further this empathy with children and to open up aspects of laboratory management and awareness of group dynamics. Backed by studies of learning processes and cognitive development the platform is laid for student teachers to begin to plan teaching strategies and learning experiences for pupils. Initially work is done with small groups of children in preparation for facing whole classes in the laboratory.

Another feature of the science curriculum programme which complements basic science and teaching practice is a one-week course at a residential field centre. Here students gain practical experience in field study skills, explore resources provided by numerous environmental agencies and learn how to use the environment as a teaching resource. This experience is especially valuable for many chemistry and physics graduates who may not have undertaken ecological courses which are familiar to most biologists. Here they have opportunity to plan learning activities and to manage pupils in the 'outdoor classroom' with the co-operation of local schools which make classes available.

Objectives and Outcome

College tutors engaged in the science methods course keep in mind the set of objectives listed in Appendix 1. These objectives have been discussed in the past with heads of school science departments and it is proposed to renegotiate them with schools that volunteer to participate in the area-based programme. When interpreting these objectives it should be remembered that students have remarkably different educational backgrounds and unique personalities. It is not the intention to shape every student into a common mould. Rather, the aim is to help students to acquire an essential set of competencies, a new measure of self-awareness and confidence and an appreciation that initial teacher education is but the beginning of a formative process in which pupils will play a major role provided the new teacher has the capacity to read the pupils' messages. Furthermore the expectation is encouraged that first appointment induction training and regular in-service training are essential follow-up to the PGCE year.

Evaluation

A small scale trial of the area-based programme is currently in its first year. At the time of writing it is too early to make evaluative judgements. Feedback from schools is generally encouraging. Teachers are enjoying the greater involvement but are finding the additional work heavy. Next year schools will receive some limited additional funding that will go some way towards eliminating this problem but it is perhaps fair to say that the politicians may not have calculated the full costs of fully resourcing the approach to teacher education which they advocate. The new course will be evaluated termly by feedback by student groups, including the science subject group and cross-curriculum groups who share the same schools for the professional course. Her Majesty's Inspectorate will certainly monitor our scheme and it is usual for us to commission an independent evaluation. The scheme will begin with the benefits of volunteer schools and the Institute going forward into the programme of its own volition. These factors should ensure that the new scheme is given a favourable climate. It remains to be seen whether the ideals of the teacher educators will be matched and shared by hard pressed inner city teachers. It also remains to be discovered whether emergent teachers will have 'space' in these schools in which to develop creatively in the way that was possible in the past

when they were not so tied by their school commitments.

Schools are looking very positively for benefits from the new scheme. They are expecting an enrichment from their regular contact with a small team of university tutors. Additionally they expect to benefit in the eyes of parents from the status of being a 'training school' and teachers involved see this as an accolade to appear on their *curriculum vitae*. These are the expectations of the parties involved in the changes described, but if the legislators force the pace of change by statute it will be difficult to reverse the situation because money will certainly be diverted from higher education to schools to help finance their part in teacher training. This will inevitably set in train staff reductions in teacher education departments which will impede any policy reversal should expectations of the new approach fail to materialise.

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Appendix 1:

A Set of Objectives for the PGCE Science Curriculum Course

SCIENTIFIC COMPETENCIES

1. Scientific Knowledge

So that new teachers are competent to teach broad science to pupils aged 11-14 and more specialist science courses to 14-19 year olds the course involves every student in consideration of:

- broad scientific concepts fundamental to national curriculum science;
- perceptions of the processes of science and the nature of science;
- the interaction of science with society;
- the interaction of science with technology;
- the use of the environment for science education;
- the essential concepts for teaching one science to advanced level.

2. Laboratory Skills

Students are expected to:

- perform standard laboratory procedures;
- demonstrate effectively the use of standard laboratory apparatus;
- use a microcomputer with interfacing devices for recording experimental data.

3. Health and Safety

Students are expected to:

- have knowledge of health and safety regulations relating to schools and field excursions;
- be reliably safe in the activities they and their pupils perform in science lessons;
- appreciate the importance of safe storage of laboratory chemicals and scientific apparatus;
- (Biology specialists) know how to maintain selected plants and animals for teaching purposes and apply national and local guidelines for their use with pupils.

TEACHING SKILLS

1. Pedagogy

Students should develop skills which enable them to:

- organise appropriate learning experiences for pupils of a wide range of abilities;

- organise and manage lessons including laboratory practicals;
- select and use effectively a range of learning materials and technological resources available in schools;
- use a microcomputer as an inter-active learning tool;
- employ a wide repertoire of teaching strategies;
- show sensitivity to the needs of individual pupils, including slow learners, bi-lingual pupils and gifted children;
- provide pupils in their classes with equality of access to the science curriculum.

2. Assessment

Students to be introduced to assessment procedures and experience them in school so that they:

- can monitor and record pupils' progress and achievement;
- are able to perform basic assessment techniques and are familiar with the repertoire of assessment instruments;
- are informed about changes in the school examination system and development in graded assessment and profiling.

3. Evaluation

Students are to develop skills in:

- evaluating a lesson;
- evaluating a discrete science unit in a course;
- evaluating a curriculum project.

PERSONAL DEVELOPMENT

During the PGCE course tutors will expect to see and encourage in each student:

- development of confidence and conscious awareness of personal strengths and weaknesses;
- ability to learn from experience;
- ability to work collaboratively with colleagues;
- gradual emergence of a personal philosophy of education and a professional code of conduct;
- qualities appropriate to the role of a class tutor.

Appendix 2

Science School-based Days

The objectives for these days are that students should:

- receive an introduction to the school and to the science department from people in positions of responsibility in the school;
 - learn what is considered appropriate behaviour when working as a teacher in the environment of a school;
 - acquire some degree of skill in observing science lessons purposefully;
 - observe a diversity of science teaching and learning including some of a high standard;
 - through discussion as a group with their science tutor, develop some understanding of the purposes and methods of science teaching/learning which they observe, and a recognition of the distinction between teaching and learning;
 - begin to understand the simpler aspects of how children learn, and the wide range of attainment to be found in a typical class;
 - gain some appreciation of the skills required to manage the learning situation within a science laboratory (including managing pupils, learning, safety, equipment);
 - gain some appreciation of the language appropriate when teaching pupils of different ages and attainments;
 - undertake some initial planning of one or more science lessons, and thereby gain some appreciation of the diversity of aspects which have to be considered if a science lesson is to be delivered effectively;
 - take a degree of responsibility in working with pupils, for example by introducing a section of a lesson with a whole class, or by working with a small group of pupils, or by participating in a team;
 - begin to develop ways of monitoring and evaluating their own effectiveness in the teaching/learning situation with a view to improving it;
- gain some appreciation of the ways in which a science department functions as a whole.

Appendix 3

Components of the Science Curriculum Course

1. Basic Science

Each topic includes

- i. science knowledge
- ii. practical work for school science
- iii. a pedagogical dimension.

Process skills: measurement

Energy	Light
Materials	Forces
Electricity	Electronics
Senses	Technology
Life processes	Earth science
Particles	Earth in space
Pollution	

2. Other Topics included in the science course

Approaches to teaching science	Mathematics and science
Safety in science	Assessment in science
Health education	Teaching about the history and nature of science
Computers in science	Teaching biology, chemistry or physics to advanced level
Bilingual learners in science	Use of museums in teaching
Childrens' learning in science	

TECHNOLOGY, SCIENCE AND THE ENGLISH TRADITION OF LIBERAL EDUCATION

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INTRODUCTION

The challenges posed to the Australian Education System by economic and industrial change have been discussed in a recent paper by John Mathews and colleagues (1988). An interesting feature of this paper is that it is premised on the proposition that 'flexible skill formation and the development of technological literacy' are 'the preconditions of any citizen to be active in the democratic system'. This assertion supplies a very new answer to a very old question, namely that of identifying the basic elements of the education of a free citizen. Questions about the nature of a 'liberal education' were formulated and answered, according to his lights, by Aristotle. Pride of place in Aristotle's scheme were given to music and gymnastics, learning about technology being excluded *a priori* as intrinsically degrading. Given the chasm in time and circumstances separating classical Athens from modern Melbourne, it is hardly a surprise that both Aristotle's preconceptions and prescriptions differ so markedly from those of his Australian successors. What is genuinely surprising, however, is the durability in the English speaking world, of the Aristotelean categories of 'liberal' and 'illiberal'.

John Dewey (1913), in a famous essay written early this century, reviewed the shifting conceptions of a liberal education which accompanied the political, economic and intellectual evolution of western societies. More recently, Sheldon Rothblatt (1976) has published a detailed study of this process as it occurred in 18th and 19th century England, where many factors combined to sow confusion about educational aims and methods. The eighteenth-sixties, the decade of the Second Reform Bill was a period of particular turbulence. Matthew Arnold's (1868) *Culture and Anarchy* bears eloquent testimony to the social, political and religious ferment of those times. It also came to be accepted as a classic reformulation of the aims of liberal education in terms of the attainment of 'culture'. Arnold's notion of culture was crisply summarized by his friend and adversary Thomas Huxley (1893) in the following terms:

... a criticism of life is the essence of culture ... literature contains the materials which suffice for such a criticism.

Although the near monopoly of classical language and literature in the curriculum of schools for the English upper classes was not seriously challenged in practice for many years, this particular version of the liberal curriculum was, at the time of *Culture and Anarchy*, under attack from several quarters. The slow process which would open up the curriculum to 'modern' subjects had already begun. Engineering subjects, for example, had gained acceptance at a number of university level institutions. A broad account of these developments has been given by Eric Ashby (1958).

The purpose of this paper is to discuss the terms on which scientific and technical subjects were incorporated into the English educational system. The most important theme, and one which is almost unavoidable in any discussion of English educational history, is that of class stratification. The work of Rothblatt and Ashby, although valuable and interesting, can be criticised for largely neglecting the class dimension. No such criticism, however, can be levelled at Dewey, whose essay begins by drawing attention to the extent to which Aristotle's conceptions of liberal education were rooted in the particular class relations of classical Athens, and is generally concerned with the relationship between ideas of liberal education and ideas of class.

Class and Education are currently both in the mainstream of political debate in the U.K. All political parties aspire, at a rhetorical level at least, to banish class divisions and 'classlessness' has become a badge of political respectability. The education system, widely regarded as inadequate, is the object of remorseless political scrutiny. There are particular worries about Science and Technology education. The Royal Society (1991) has recently published an authoritative report on post-16 education in the light of 'future scientific, mathematical and technological needs of the U.K.' In their opinion: