WHAT IS LEARNED AT UNIVERSITY

SOMUL

The Social and Organisational Mediation of University Learning

An ESRC TLRP funded project being undertaken by the Centre for Higher Education Research and Information of the Open University and the Centre for Research in Lifelong Learning of the University of Stirling

Biosciences: An Overview of Undergraduate Studies in the UK

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T·L·R·P TEACHING & LEARNING RESEARCH PROGRAMME

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Foreword

This is one of three subject overview reports that have been prepared as part of the SOMUL project (the full title of the project is *What is learned at university? The social and organisational mediation of university learning (SOMUL)*). The project is part of the Teaching and Learning Research Programme (TLRP) funded by the Economic and Social Research Council. SOMUL is being undertaken by a research team from the Centre for Higher Education Research and Information and the Institute of Educational Technology at the Open University and the Centre for Research in Lifelong Learning at the University of Stirling. The aim of the project is to increase our understanding of the learning outcomes from an increasingly diverse higher education system and to investigate how these are socially and organisationally mediated.

The present phase of the project is focusing on student learning in three subjects: biochemistry, business studies and sociology. Students studying in five different university settings in each of these subjects are being asked about their experiences and their perceptions of learning over a two year period. As part of the context setting for the study, overview papers have been prepared for each of the three subjects. The purposes of the overviews are two-fold: (i) to sensitise the research team to subject cultures and issues relevant to designing and conducting the fieldwork; (ii) to provide a basis for eventual comparison of empirical findings on the three subjects and the assessment of their applicability to other subjects. Later in the project, we shall be investigating student learning in a further five subjects.

We are grateful to the authors for preparing these reports and to the support provided by the three relevant subject centres of the Higher Education Academy. All three reports and further information about the SOMUL project are available on the project website at www.open.ac.uk/cheri/SOMULhome.htm.

John Brennan
Project Director
August 2005

Section 1: Introduction

This purpose of this paper is three-fold. First, it is concerned with an examination of aspects of the current provision of undergraduate programmes in the biosciences in the UK. It is produced in conjunction with the Higher Education Academy (HEA) and the Centre for Bioscience as part of a wider ESRC/TLRP funded research project: 'What is learned at University: The Social and Organisational Mediation of University Learning' (SOMUL). The second purpose is to briefly review some of the literature as it relates to developments in discipline specific teaching and learning as reported in subject related academic journals. This will focus on aspects of curriculum content and design, developments and innovations in delivery and assessment and the use of technology. Finally, it will provide some details of the students who enrol and graduate from degree programmes listed under the Joint Academic Coding System (JACS) category C – Biological Sciences.

The aim of the SOMUL project 'is to increase and broaden our understanding of the learning outcomes of an increasingly diverse higher education system, explore how these are socially and organisationally mediated, and support their enhancement and fuller recognition.' (Brennan and Jary, 2005) Three disparate subject areas were chosen (Bioscience, Sociology and Business Studies) and five case study institutions for each subject area were recruited. A summary of the overall project is attached as an appendix.

In order to inform the selection of case study institutions, the SOMUL team contacted a number of institutions on a list of possible participants provided by the Centre for Biosciences. Eight institutions amenable to participation were visited from which the final selection of five was made. Each visit normally included at least two members of the SOMUL team and two or more relevant staff members at each prospective institution. Criteria for selection included how each institution could be defined using the concepts of organisational and social mediation (Brennan and Jary, 2005). Diversity in the organisational and social mediation of learning was a major criteria for inclusion in the research. To this end, organisational mediation was operationlised, for example, in the degree of flexibility in the curriculum, or in how students and staff are organised in either relatively closed or open systems. In terms of social mediation, this was reflected *inter alia* in the social mix of the student body (in terms of race, class and gender), and in whether the student body was local and commuted or largely residential and catering for 'outsiders'. One further related measure of diversity was the campus form (self contained) and its location (city centre/satellite/rural). On the basis of these forms of diversity in organisational and social mediation the selected institutions broadly reflected the range of provision available in the that part of biosciences in which biochemistry was a common feature.

Biosciences cover a broad spectrum of sub-disciplines and the subject of Biochemistry was chosen as a focus since it is found in some 50% of courses within the Subject Centre. Thereafter it was possible to represent diversity both in terms of provision, institutional type and the demographics of the student intake by selecting provision that ranged from single honours Biochemistry through to highly modular general biosciences degree within which Biochemistry was a minor element. However unlike the discipline itself this choice of provision to represent diversity is not an absolute science. Effectively most courses are modular and at an individual level it is not possible to predict the ultimate path to a particular degree that students take with certainty. Within most of the institutions selected as case studies, the majority of courses contain a common core for at least the first year, before a specific choice was made from one of perhaps six to eight single honours specialisms.. After the common core, students then make specific choice from one of perhaps six to eight single honours specialisms. By selecting courses in which Biochemistry was an element of the broad initial programme offer, it has not only been possible to represent diversity of students and provision, but also allowed the inclusion of a large and representative sample.

Section 2: Context

Bioscience encompasses a huge range of biological and biology-related subjects, from Agriculture to Zoology, and includes such topic areas as Ecology and Bioinformatics (Figure 1). All of these are experimental sciences where subject content is derived from observation, experiment and interpretation, and all have very wide implications in the agricultural and pharmaceutical industries as well as in medicine (including nutrition).

Thus, the biosciences can be broadly defined as essentially practical and experimental subjects and as such opportunities should exist to participate in collecting data through experiments and investigation. In some areas this may be through the use of field work, in the laboratory, or as a combination of the two methods.

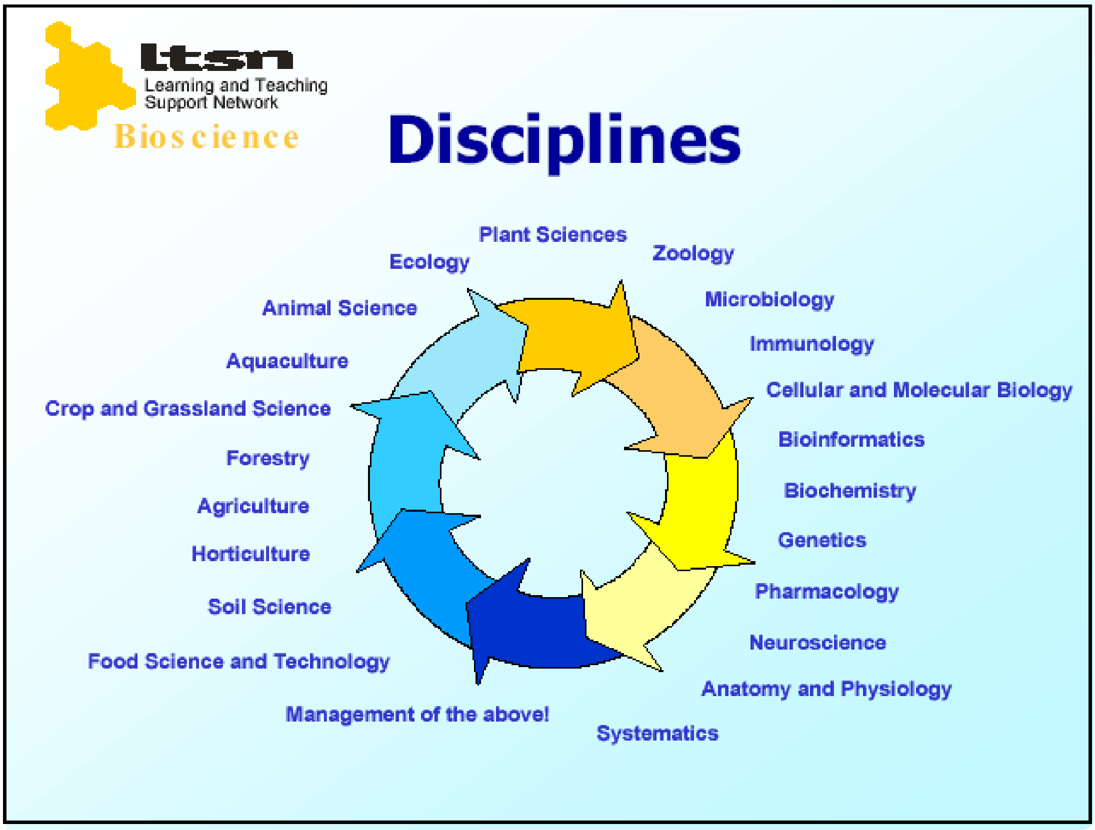

Figure 2.1: Subject Areas within Bioscience (Centre for Biosciences, 2005)

Figure 2.1 is not exhaustive and as an area where knowledge is expanding there will be additions to those subjects contained above either in their own right, or as combinations of existing subject areas. This issue is one which has been recognised in the subject benchmark statement for the Biosciences (QAA, 2002). While the term ‘Bioscience’ has only gained common usage in recent years and is found in relatively few titles of programmes, degrees or departments it was felt that no other word embraced the whole range of what is now regarded as a single subject (*ibid*.: p1). One source, which attempts to classify the range of courses offered in the biosciences, and which is intended to provide information and advice to prospective entrants in this field is the CRAC Degree Course Guide: Biological Sciences (2004).

A further source of information on the composition of undergraduate bioscience courses in the UK is provided in the subject benchmark statement produced by the Quality Assurance Agency (2002). The membership of the group contained a wide variety of specialist interests although due to size limitations it could not contain an expert in every field falling within the biological science remit. Nevertheless most areas were represented as efforts were made to ensure that members had some familiarity with the various sub-disciplines. There was some scepticism regarding the value of benchmarking within the group at the outset and according to the statement this was never completely resolved. However, the group 'was united in trying to produce benchmarks that would be useful without being a barrier to unconventional or novel ideas, or to multi- or inter-disciplinary approaches.' (QAA 2002: p1)

Initially the benchmark provides some context within which to situate the issues raised in the statement. Citing recent advances (e.g. cloning, genetically-modified organisms, the human-genome project) and media and public concerns about the development and use of such knowledge and about human influence on the environment, the potential risks of certain foods and many similar topics, the benchmark statement draws attention to the contribution that the biosciences can make to the development of both the health and wealth of a nation.

> *'Fundamental understanding of diseases, for example the role of micro-organisms, together with the development of new vaccines, drugs and antibiotics, has saved many lives. But new developments that most biologists view as progress may alarm other people and the influence of the human species on the natural world has not been without costs. In recent times human activity has disturbed the environment to an unprecedented extent. We have now reached a point in the earth's history where knowledge of biology is essential for a viable human future. It is therefore important for leaders of society whether in government, industry, business or education to appreciate this and for an informed electorate to understand the scope and limitations of biological knowledge and techniques. Only then can we face the challenging social, ethical and legal problems posed by new developments such as stem cell cloning, gene patenting and gene therapy while working to maintain biodiversity and a stable and sustainable environment.'(op.cit.: p1)*

Standards and design

While it is recognised that the specific focus will in large part be determined by the degree title and normally related to one or more of the disciplines reported in Figure 1, there are also a number of commonalities in both knowledge and practice which cut across the boundaries of the individual disciplines which collectively reflect the contemporary state of bioscience delivery in UK undergraduate degree programmes. The development of a range of very similar intellectual and technical skills referred to above means that movement between different fields is relatively common both for the purposes of employment and for the study of higher degrees.

As recognised in Figure 2.1, and as stated in the Benchmark Statement (QAA, 2002), the biosciences are studied under many different titles and in many different departments, faculties, schools and institutions. Some will be concerned with ecological issues and work in the field. Many will work in laboratories albeit in different contexts. These would include not only university departments, but also the biotechnology, pharmaceutical, health and food industries.

The biosciences are concerned with the study of life at all levels of complexity from the molecular to the level of populations. From a start point of individual atoms it encompasses the organisation of 'life' in molecules, cells, tissues and moving in scale and focus to organs, organisms, communities and ecosystems. Drawing on the work on Darwin on natural selection and aided by recent advances in genetics and molecular biology it seeks to provide a greater understanding of life's basic processes. Thus, life is viewed, and studied as an 'intricate balance of interactions between an apparently infinite variety of life forms and finite inanimate resources.' (QAA, 2002: p.2)

> *'The biosciences are a family of methods and disciplines grouped around the investigation of life processes and the inter-relationships of living organisms. This may involve studies at a variety of levels from molecules to populations. All students should have at least some appreciation of all of*

> *those levels. There is always significant interaction between them. In the past few decades, many people working in disciplines that might previously have been classified with the physical sciences such as organic chemistry, engineering and software development have begin to collaborate with biologists to form multi-disciplinary teams tackling topics such as the human genome project and bioengineering.' (QAA, 2002: p2)*

Issues of complexity and the relationship between form and function are seen as intrinsic to the biosciences. While some bio-scientists may be concerned with reducing complex systems to their component parts, all are concerned with working with organisms that may be difficult to understand and influenced not only by the environment but also through interactions with other organisms. In addition, the biosciences currently operate in a realm of current hypotheses rather than in an uncontested certainty which necessitates that students be aware of alternative hypotheses and how to empirically investigate and critically evaluate these. Further, in certain areas, including those such as genetics and molecular biology new knowledge and technologies are emerging which requires graduates to be cognisant of these and other developments in what is a rapidly changing field.

However, before looking in detail at what might be found in an undergraduate biosciences degree programme, it is instructive to note the comments of the Biochemical Society (2002) in regard to the changing nature of the composition of the secondary school science curricula. (For a critical analysis of school science curriculum reform, see Donnelly, 2005) The Biochemical Society note, that a number of changes have occurred within school curricula that have resulted in a reduction of factual content in most science subjects. Using chemistry as an example, they suggest that since 1990, the syllabus has been reduced by around a third in line with the new pre16 science curriculum. It is suggested that this has an impact on the knowledge and skills which entrants to biosciences bring with them which has resulted in changes to some first year provision to ensure that entrants have the requisite core knowledge and competence in basic practical skills required in the laboratory. Leggett (BSF, 2003) details some of the changes and the rationale behind these changes. According to the Qualifications and Curriculum Authority (QCA, 2003) most pupils do not pursue scientific careers so the compulsory science curriculum is focused on what it terms 'scientific literacy' in order to enable young people to understand scientific advance and hazards as reported in the media. However, as Leggett recognises, this would not in itself be adequate provision for a career in science. This can then result in students applying for and being accepted on biosciences courses without 'A' levels in Chemistry and Maths. This then leads to a situation whereby many first year undergraduate courses are required to provide remedial support and extra tuition to get all first years up to the required standard.

Despite the plethora of titles under the bioscience umbrella, it is suggested that most courses in the biosciences, especially in the first year, will deliver reasonably similar material with changes of emphasis dependent upon the exact nature of the degree programme and the nature of the specific discipline. Indeed, the Benchmark Statement do not identify much factual information that should be present in an undergraduate bioscience programme '*other than the obvious, the trivial or the banal that should be expected of every student working in the biosciences*.' This is justified with recourse to the fact that: '*the subject is too wide and diverse for that to be useful*.' Thus, they concentrate rather on the skills and attributes acquired which would equip the bioscience graduate for a career in biosciences or elsewhere. However, they do provide some general guidance as to what would constitute 'threshold' and 'good' standards both for generic bioscience provision, and as they relate to specific areas of the biosciences at the molecular level, the organismal level and in areas concerned with ecology and the environment.

Before examining the standards mentioned above, attention will first be focused on subject knowledge that is likely to be common to all bioscience programmes. This is broken down into eight different sub-sections covering: subject knowledge, generic skills, graduate and key skills, intellectual skills, practical skills, numeracy, communication and information technology skills, interpersonal and teamwork skills, and, self-management and professional development skills (QAA, 2002: pp3-5). While it is recognised that differences in focus and institutional context will have an impact on programme design and that no provider has the resources to cover all aspects students, in any specific discipline, should expect to be confronted by some of the relevant scientific, moral, political and ethical questions and to be able to consider alternate viewpoints and engage in the critical and intellectual arguments which these issues raise in contemporary society.

Subject knowledge that should be common across programmes includes a broadly based core of knowledge defined by the specific programme and set within the wider context of the overall subject area.

> *'Whatever the degree programme, there is a need for an interdisciplinary and (where appropriate) a multi-disciplinary approach in advancing knowledge and understanding of the processes and mechanisms of life, from molecular to cellular, and from organism to community.' (QAA, 2002: p3)*

There should also be engagement with the essential facts, concepts, principles and theories associated with the chosen discipline and knowledge of the processes which shape the natural world and to situate this within a theoretical framework using appropriate terminology, nomenclature and classification systems. Student should also be equipped with methods for acquiring, interpreting and analysing biological information from texts, original papers, reports and data sets. Moreover, students should be made aware of the contribution of their area to the overall development of knowledge about the diversity of life and its evolution and be able to apply and disseminate this knowledge through appropriate practical and presentational techniques. Finally this should be situated within contemporary society and engage with the philosophical and ethical issues which this raises.

Many of the related numerous skills and competencies associated with communication, teamwork, and critical intellectual development would perhaps be expected to be common in all undergraduate level courses. The generic skills which are seen as specific to bioscience programmes are situated within a context where students should recognise that much of what is taught is contested and provisional in an environment of continuing scientific advance. Table 2.1 illustrates the main generic skills expected to be acquired through the study of biosciences although only the first is truly specific to biosciences.

Table 2.1: Generic skills in the biosciences (QAA, 2002: p4)

Generic Skills
An appreciation of the complexity and diversity of life processes through the study of organisms, their molecular, cellular and physiological processes, their genetics and evolution, and the interrelationships between them and the environment;
the ability to read and use appropriate literature with a full and critical understanding, while addressing such questions of content, context, aims, objectives, quality of information, and its interpretation and application;
the capacity to give a clear and accurate account of a subject, marshal arguments in a mature way and engage in debate and dialogue both with specialists and non-specialists;
critical and analytical skills: a recognition that statements should be tested and that evidence is subject to assessment and critical evaluation;
the ability to employ a variety of methods of study in investigating, recording and analysing material;
the ability to think independently, set tasks and solve problems.

Having now provided a broad brush approach as to what should be components of any undergraduate biosciences programme, it is now useful to look at more specific interpretations as contained within the standards for biosciences in general and for some specific disciplines. These standards are classified as 'threshold' and 'good'. The 'threshold' standard should be achieved by anyone obtaining an honours degree, even those placed towards the bottom of the third class classification while the 'good' standard is significantly higher and should be achieved by someone achieving an upper second class classification. However, attention is drawn to the work of Curran and Volpe (2004) concerning the variability in performance across institutions required to obtain a 'good' degree.

The first table (Table 2.2) compares the standards which all honours graduates in bioscience would be expected to achieve at the 'threshold' and 'good' level irrespective of area of study. The second (Table 2.3) then examines the standards (at the 'good' level) for a number of specific areas.

Table 2.2: Generic standards (QAA, 2002: p8)

Generic standards, not specific to any particular area	
'Threshold'	**'Good'**
Be able to access bioscience information from a variety of sources and to communicate the principles in a manner appropriate to the programme of study;	Be able to access and evaluate bioscience information from a variety of sources and to communicate the principles both orally and in writing (e.g. essays, laboratory reports) in a way that is well organised, topical and recognises the limits of current hypotheses;
Have ability in a range of practical bioscience techniques including data collection, analysis and interpretation of those data, and testing of hypotheses;	Demonstrated ability in a range of appropriate practical techniques and skills relevant to research in the biosciences. This will include the ability to place the work in context and to suggest lines of further investigation;
Have an understanding of the explanation of biological phenomena at a variety of levels (from molecular to ecological systems) and be able to explain how evolutionary theory is relevant to their area of study;	Have a secure and accurate understanding of the explanation of biological phenomena at a variety of levels (from molecular to ecological systems) and be able to understand the relationship of evolutionary theory to their area of study;
Be able to plan, execute and present an independent piece of work (e.g. a project) within a supported framework in which qualities such as time management, problem solving and independence are evident;	Be able to plan, execute and present an independent piece of work (e.g. a project) in which qualities such as time management, problem solving and independence are evident, as well as interpretation and critical awareness of the quality of evidence;
Have some understanding of ethical issues and the impact on society of advances in the biosciences;	Be able to construct reasoned arguments to support their position on the ethical and social impact of advances in the biosciences;
Be able to record data accurately, and to carry out basic manipulation of data (including qualitative data and some statistical analysis where appropriate);	Be able to apply relevant advanced numerical skills (including statistical analysis where appropriate) to biological data;
Have developed basic strategies to enable them to update their knowledge of the biosciences.	Have well developed strategies for updating, maintaining and enhancing their knowledge of the biosciences.

Table 2.3: Subject specific standards (QAA 2002)

Subject-specific standards ('good')		
Molecular aspects of biology (inc. Biochemistry)	**Organisms**	**Ecology and Environmental Biology**
Understand and explain the chemistry that underlies biochemical reactions and the techniques used to investigate them;	Critically analyse the impact of external influences on growth and reproduction and explain reproductive strategies;	Demonstrate comprehension and intelligent engagement with biogeochemical cycles and pathways;
Understand the principles that determine the three-dimensional structure of biological macromolecules and be able to explain detailed examples of how structure enables function;	Critically recount the interactions of structure and metabolic functions at cellular and organismal levels;	Discuss and demonstrate comprehension of nutrient and energy flow through individuals, populations and communities;
Have a critical understanding of the basis of genetics, and be able to explain some detailed examples;	Describe and critically evaluate the evidence for the mechanisms of life processes;	Demonstrate comprehension of the structure, biogeography and diversity of ecosystems in relation to climate, geology, soils, paleo-historical and evolutionary factors;
Have a critical knowledge and understanding of gene expression, with a detailed knowledge of specific examples; the structure arrangement, expression and regulation of genes; relevant experimental methods;	Interpret the significance of internal and external influences on the integration of metabolism for survival and health;	Discuss and critically analyse patterns of distribution of organisms in relation to biotic and abiotic factors;
Be familiar with a wide range of cells (both prokaryotic and eukaryotic) and be able to explain critically how their properties suit them for their biological function, and how they could be investigated experimentally;	Describe and analyse patterns of inheritance and complex genetic interactions;	Demonstrate comprehension and critical analysis of population processes, dynamics and interactions, and associated models;
Be able to devise and evaluate suitable experimental methods for the investigation of relevant areas of biochemistry and molecular biology;	Enumerate the methods and principles underlying taxonomy and classification;	Evaluate and critically analyse the effects of such human interactions on natural populations and ecosystems;
Have a critical understanding of essential features of cell metabolism and its control, including topics such as energy and signal transduction, respiration and photosynthesis. This should include knowledge and experience of some experimental techniques;	Critically describe the principles and processes governing interactions of organisms and their environment;	Evaluate the impacts of harvesting resources, controlling pest/pathogens and different approaches to species management;
Understand the chemical and thermodynamic principles underlying biological catalysis and the role of enzymes and other proteins in determining the function and fate of cells and organisms.	Critically analyse the contribution of the organisms to the biosphere;	Apply critical understanding of ecological methodologies and data analyses.
	Critically assess the contribution of 'behavioural patterns' to survival and success.	

In comparing the different levels, the main differences between 'threshold' and 'good' are concerned with the depth of understanding, the level of interpretation and the degree of critical awareness and cognitive development expected to be achieved.

Structure and content

Having outlined some of the standards in undergraduate bioscience provision, how are courses structured? Courses are taught (mostly as modules at present) for single-subject BSc, joint honours BSc (e.g. Microbiology and another subject which may be another bioscience or might be Computing, Business Studies, or French), or delivered as 'service teaching' to medical, dental and veterinary courses (usually in the first year or two). In the case of medical, dental and veterinary students, the Biosciences taught was mostly 'theoretical' in order to engender an understanding of life processes and the effects of drugs on these. It was not expected that practical laboratory skills would be developed to any significant extent, although it is clearly important for such students to have an understanding of the results and significance of the 'tests' carried out on blood and urine etc, by clinical chemical laboratories. However, the situation is changing since nearly all the medical schools have gone over to an integrated curriculum. The various divisions (Biochemistry, Physiology, etc.) are barely recognisable as such although much of the material (though now reduced in content) is still taught by the Bioscience departments.

Most BSc courses in England and Wales are three-year courses (compared with four-year in Scotland and N Ireland), but there are significant exceptions. Oxbridge has always had four-year courses, and some English universities offer four-year courses that lead to for example the award of an MBiolSci degree rather than a BSc. In addition, a number of university Bioscience departments now offer the possibility of a 'year out' between years 2 and 3 (e.g. the final year) in industry, or in another country. The year in industry may be 'paid' in the sense that students earn a salary during this period. A year out in another country might be within an ERASMUS-type scheme (although relatively rare these days) or simply on the basis of an exchange agreement made with another university. Employment in another country is also possible in some cases. Practice varies widely as to whether such years involve credit transfer: it is almost impossible to summarise what might be common practice. Such 'sandwich' schemes are now very popular, giving students a chance to experience the 'real world', perhaps to earn some money, and also to travel. In a few universities the year out is mandatory. In others, it may be subject to competition based on performance but in most it is optional on either an 'opt in' or an 'opt out' basis. Typically 25% of students may take this route but figures are very variable across the universities of the UK. It is inherently assumed that such schemes will give students an added advantage in terms of subsequent employability.

The structure of courses, or component modules, in Biosciences would be very much the same in all universities, as indeed would be the 'content' of what is taught. There will be variations in emphasis and focus dependent upon the specific named degree title. What is taught to medical students is clearly going to be different from that taught to agriculture students, but such is the unity of the chemistry, structures and reactions, that there will be a great deal of commonality. The other aspect to this is that there is such a huge volume of accumulated knowledge that in general it is considered that there will inevitably be a degree of specialisation since no one person can know it all. This is recognised by either giving students a choice of modules or by labelling the degree schemes to indicate their 'flavour' as such. Thus one may take Genetics, Molecular Biology, etc, either as chosen modules or as the whole degree scheme. In some cases, this is taken a step further, with all entrants to a department studying a common core providing grounding in the basics of knowledge and technique before making a choice, often at the end of first year, from perhaps six to eight optional single or joint honours specialisms.

A typical bioscience module will have lectures and laboratory practical work in roughly equal proportions, plus some tutorial, seminar or other sessions, depending on the university and the year or level of the course. The final year will be somewhat different, much time being devoted to a 'research project' taking up perhaps one-third of the time (discussed below). The lectures in years 1 and 2 (NB 2 and 3 in Scotland) will tend to be factual delivery of material for the most part, but lecturers will normally aim to bring their own (research) experiences into what they deliver in order to enthuse students and offer an up to date view (in a fast-moving area). The lecture will also emphasize the importance of the experimental approach: it might deal specifically with instrumentation and laboratory methodology, for example, not just from the technical point of view, but also from the intellectual point of view, i.e. how and why certain experiments were done and how the results were interpreted. The size of lecture classes tends to be quite large: typically several hundred in the first year, to 50-100 in the second year. Lab classes will also be large, but most departments run these in small groups (e.g. 16-20 students), working in pairs, with a post-graduate as a 'demonstrator' supervising that group, all doing the same experiment and using the same equipment. Demonstrators also mark written up lab reports, and the lab component may account for perhaps 20% of the mark for the module (though this varies). Tutorials or seminars tend to be in groups of 8-12, supervised by a staff member or a 'teaching fellow' (in general someone with more teaching experience than a postgraduate). In these groups students undertake a variety of activities, focussing not only on trying to understand the biosciences, but also on developing transferable skills such as writing essays, making short presentations, problem-solving, working in groups, etc. Marks may be given in such classes that contribute to the final module mark. These so-called transferable skills are an important component of Biosciences courses. Scientists in their careers cannot function without numeracy and data analysis skills, but such skills are valuable in a wide variety of careers other than in the biosciences for example in finance, banking and insurance. There may be tests (e.g. multiple-choice tests) at intervals during the module (that also contribute to the final mark), and at the end of the module there will be a written examination involving (usually) multiple-choice, short answer, and essay-type questions. Practice varies widely and is influenced by the size of the class (e.g. can the assessment be computer-marked?), the desire to give effective feedback, to test the skills it is hoped are being developed, etc. In general first-year classes are more likely to be assessed by multiple-choice and second-year by essay-type questions.

The third year of most biosciences courses involves a research project of some sort, and the importance of this is recognised both by the *Benchmark Statement for Biosciences*, and, by the *Recommended Curriculum of the Biochemical Society* (1997). The project might make up about one-third of the final year (see below). The rest of the year will be taken up with typical modules except that these will normally contain rather little or no practical work (since this is being done in the project), will be cutting-edge, taught by people active in research, and in many universities, taught on the basis of papers in the current scientific literature. This will involve students learning how to read scientific papers (and short courses on this may be given), learning how to do technical writing within the conventions used, how to write abstracts, read and present graphs and tables, etc. These are seen as vital skills for the graduate. Assessment may be by the writing of short reviews of current topics, writing abstracts for papers from which the abstract has been removed, data-handling exercises, as well as typical essay-type questions in final examinations.

The final-year research project was originally a laboratory research project in which a student joined a research lab for several months and engaged in original research, supervised by a member of staff. For the most part this still applies, but at the present time some alternatives may be offered to some students. These will typically be extended literature surveys, extended exercises such as writing a grant application, or computer-based projects (see below).

The so-called 'wet' lab project gives the student a first hand experience of working in a research laboratory on an original although perhaps limited question. This is a highly significant experience for the majority of students (and prepares the way for those who intend to continue to PhD). It gives a flavour of what it is really like to be a 'bioscientist', presents a challenge, usually involves team work with the post-grads and post-docs in the lab, encourages independence in thought and technical work, but also deals with the issues of dependability and reliability, and the ability to contribute to the team effort. Students experience the 'culture' of a research laboratory.

The actual period spent in the lab varies quite widely. It might be between 12 and 20 weeks, but it may also be recommended that only three full days be spent in the lab not five. In some universities it is carried out after the final examination papers have been taken at around Easter (and then would be full time). Students have the opportunity to recognise that working in a lab is not a nine-to-five job: it depends on the nature of the experimental work, the time intervals in which samples have to be taken, and also when one can get onto the equipment for example. This is an invaluable learning experience for them. They will normally have a close relationship with their supervisor in directing the work at this time, and also many of them will be helped and supported by the post-grads, postdocs and technicians in the lab. They also begin to realise that there is “no right answer” that in new work experiments have to be repeated and repeated until one is confident, and that data need to be evaluated and statistical tests applied, and so on. It represents a real experience of research, with the attendant excitements and depressions! At the end of the project period a report is normally written in the style of a scientific paper and this is read and judged by the supervisor and by a panel of independent members of staff, who may also viva the student. A mark is eventually generated from a combination of supervisor's comments on lab performance, quality of write-up and viva performance. Sometime students have to give a short presentation before the department, but this gets very time-consuming if there are 100 students in the final year class. Most students enjoy the project and find it challenging as an experience of "real life research": it certainly is a good preparation for PhD study and it is gives them a good basis for deciding whether they want a career in lab-based research – or not!

Some students elect to do a literature-based project. This may be because they know that they do not wish to continue with a career in science after graduation or, as in some departments (increasingly), only students with a good performance in their first two years may be allowed to do lab projects. It is a fact that taking a student into the lab or the field (some do fieldwork based projects) has a cost implication with respect to time, supervision, expensive chemicals and delicate equipment. Departmental contributions to the cost of the work is usually minimal compared with the cost of modern reagents and chemicals. Furthermore, "research inactive" staff may use their skills in directing literary projects, taking the teaching burden off the active researchers. Such non-laboratory projects may be highly appropriate choices for some students, especially given that around 50% of the students do not go into laboratory work. A literary project can provide training in a number of useful (for employment) extra transferable skills including data handling and numeracy.

A literary project typically takes the form of a thorough review of the recent scientific literature in a particular topic area, to be written up as a properly referenced review. Like the lab project write-up it will be marked by the supervisor as well as by an independent panel, the student may well have a viva and/or make an oral presentation to the department. In some cases it is also required that the student produces some kind of "extension" such as a short account of the significance of the topic for the layperson such as a magazine or newspaper article, or perhaps a grant proposal. Most students enjoy doing a literature survey in this way, but it has to be said that for any students serious about future benchwork or a higher degree, it would be a disadvantage to do this. (The exception to this might be students who have taken a year out in an industrial research laboratory, and would have good credentials from this, and might enjoy doing something different in their final year.)

Finally, in this section, mention should be made of the use of computers. Most employers will expect graduates to be computer-literate, capable of using word processing, spreadsheet, and presentation packages, and most students would have these skills by the end of the course. In addition, however, some parts of Biosciences involve the use of computers as research tools. Over the years, vast amounts of data have accumulated and this can only be handled by computer. One only has to think of the sequence of bases in human DNA – 3,000,000,000 in the sequence – to realise that the use of computers is vital in these areas, and there are many more examples. Much Biosciences research is actually done on the computer, looking at these sequences for patterns and characteristic motifs ("bioinformatics"). In addition, there are many applications of computers in doing complex calculations and in producing three-dimensional graphics of complicated molecules. So for at least some students, carrying out a computer-based project may be not only possible but also perhaps appropriate, depending on the career path they may have in mind. Some uses of computers in Biosciences may well be taught in some modules aside from the research project.

Overall, one may see the laboratory research project as playing a very important role in the process whereby a student is transformed from a 'mere' student into someone who is almost a practitioner in the subject. In favourable cases the results of the project work may lead to a paper published in a scientific journal, which can look very good on a graduate's CV. More or less the same may be said of computer projects, but literary project engender perhaps a different set of skills.

Biosciences is also taught on a part-time basis though not so much for a full BSc as for courses such as BTEC and HNC where the students may already be working in a laboratory (industrial, hospital, university, usually as technicians). This may be more prevalent in the post-1992 universities. Such students may attend for one day a week ("day release") which is mandatory for workers under 21 years of age, or alternatively there may be evening classes. Technicians in hospital laboratories have their own specific courses (e.g. run by the Institute of Medical Laboratory Technology) which depend on the particular type of lab in which they are working. Students of this type may decide that the qualification they obtain is sufficient for their career aims, or they may sometime transfer to full-time BSc courses, usually into the second year of a three year course.

On the international scene the content of Biosciences courses will be much the same as in the UK and the textbooks used will be similar in content. For a US perspective on some of the issues relating to the composition of undergraduate courses covered here see: for example, Huang, 2004; ASBMB, 2005. There will generally tend to be more 'basic science', i.e. Chemistry, Physics, Maths, in the first year (usually of a four-year course) based on the assumption that these are not taken to a sufficiently high level in high school. The contrary assumption in England and Wales is that these basic subjects *are* taken to a sufficiently high level in high school. This may no longer be the case in practice and a number of universities run "remedial courses" in these subjects in the first year.

Section 3: Teaching and Learning in the Biosciences

Before moving on to look at the students applying to, being accepted and graduating from bioscience undergraduate degree programmes in biosciences it is perhaps worthwhile to have a brief look at developments in teaching and learning issues in the biosciences.

As with other areas of study and in higher education in general, issues relating to teaching and learning in the biosciences have become more important in recent years. In a review of teaching and learning environments in undergraduate Biology, Hounsell and McCune (2002)[1] provide some details of the reasons underpinning the emphasis now placed on teaching and learning in higher education. They point to the large increase in student numbers and the introduction of modularisation with attendant shifts in the diversity of formats and methods of assessment. They also suggest that there is a growing and legitimate interest in what and how students are taught, in general and also in relation to the accreditation of specific courses, by professional bodies and employers. In addition, through the establishment in 2000 of the Learning and Teaching Support Network (LTSN) to promote and support high quality teaching and learning in the HE sector a number of subject specific networks were developed. These were subsumed into the Higher Education Academy (HEA) in 2004 and have been re-branded as 'Centres'.

The Centre for Biosciences (http://www.bioscience.heacademy.ac.uk) exists to provide support for discussion, dissemination and innovation in all aspects of learning, teaching and assessment.[2] To achieve these aims, it produces a range of materials promoting best practice, organises dissemination events, practice workshops and seminars, and publishes a number of resources including the bi-annual electronic journal *Bioscience Education Electronic Journal*, featuring peer-reviewed pedagogic research and practice. It also operates a range of special interest and network groups which include:

- teaching ethics to Bioscience students;
- practical work in the Biosciences;
- Problem-Based Learning in science education;
- plagiarism;
- Final Year Project work in the Biosciences;
- formative assessment in science
- Widening Participation;
- employability; and
- Biomaths.

There would also appear to be a greater emphasis on teaching and learning issues more widely in the subject area. A number of subject journals explicitly focus on education including teaching and learning issues and include: *Biochemical Education*, which became *Biochemistry and Molecular Biology Education*; the *Journal of Biological Education* and the *Journal of Science Teaching*. The papers presented may be categorised through reference to their specific focus and may feature: papers on the composition and content of courses (such as Ranaldi, Vanni and Giachetti, 1999; Feldberg, 2001; Boyle, 2004); papers on the introduction and uses of technology in bioscience education (e.g. Brown and Dystrka, 1999; Parslow, 2002); papers relating to forms and methods of assessment (Pitman, 1999; Stern, 2004; Szeberenyi, 2002); papers relating to generic and/or specific skill development (Bowen, Roth and McGinn, 1999; Campbell, Kaunda, Allie, Buffler and Lubben, 2000); and papers related to cognitive development (Marbach-Ad and Sokolove, 2000; Teichert and Stacy, 2002).

[1] Readers are directed to the associated ETL project funded by the TLRP. (http://www.ed.ac.uk/etl/)
[2] Readers are directed to the online resources to gain a detailed picture of contemporary developments in teaching and learning in the Biosciences.

Section 4: Student Origins and Destinations

In this section of the review, attention will be focused on those who apply and are accepted onto undergraduate courses which fall under the JACS group 'C' – *Biological Sciences* (UCAS, 2005) and their destinations after graduation. In the following, all data relates to academic session 2002-2003 unless otherwise specified. This particular session was chosen as this is the entry year of one cohort of students studied under the auspices of the SOMUL project. However, caution is advised when interpreting the figures, as there may be other degree programmes or elements of programmes which are classified elsewhere and which may be regarded as related to the biosciences. These would include elements of the '*subjects allied to medicine*' and elements of the '*agriculture and related*' subject groups. Moreover, the classification of *Psychology* and its derivatives are also classified under group 'C'.

Origins

A starting point to provide some context is provided by HESA (2005). Other data is constructed from UCAS data.[3] Drawing on the website (http://www.hesa.ac.uk/holisdocs/pubinfo/stud.htm), it is possible to provide information by mode of study, level of study, gender and domicile of all studying the Biological Sciences in the UK in academic session 2002-2003. The total number of students studying the Biological Sciences was 125,860 of whom: 73.4 per cent were full-time undergraduates; 10.1 per cent were full-time post-graduates; 6.5 per cent were part-time undergraduates; and 10 per cent were part-time post-graduates. Thus roughly 6 per cent of all students in higher education in session 2002-2003 were studying programmes classified under Group 'C' – *Biological Sciences*. The following table breaks down this aggregate by gender and by domicile.

Table 4.1: Domicile by gender all HE students (JACS Group 'C') – 2002/2003

	UK	EU	Non-EU
Female	63%	66%	57%
Male	37%	34%	43%
Total	114655	5590	5615

(Source: HESA 2005)

As the table above shows, there is a noticeable difference in participation in the biological sciences by gender with almost twice as many females as males studying in this area. This is quite different from the gender balance in applications and acceptances to all undergraduate programmes, with females accounting for 53 per cent in each category.

Socio-economic status

The next variable of interest is that of socio-economic status. Table 4.2 shows the number of applications to and acceptances for JACS subject group 'C'. This is augmented by the percentage of applications from each socio-economic group (SEG) and can be compared with the population share of each SEG as provided by *Social Trends 33* (2003). As can be seen, the overall picture suggests that in general: higher SEGs are over represented on the basis of their population share, in terms of both applications and acceptances; while lower SEGs are underrepresented on the basis of their population share.

This is most obvious at the extremes, with females from the highest SEG almost twice as likely to (apply and) be accepted than their population share would suggest, while at the other end of the scale, only around a third of those from the lowest SEG apply and are accepted in comparison to their population share. This is not specific to the biosciences however and a similar picture emerges when all those accepted to higher education are considered. Finally, the biosciences seem to recruit proportionately less than would be expected from applicants

[3] Thanks are expressed to the HEA for providing access to the UCAS data presented here although any errors are the responsibility of the authors.

classified as ‘unknown’. However a caveat must be introduced as the composition, with the exception of overseas students, of those classified as ‘unknown’ cannot be determined.

Table 4.2: Socio-economic status by gender Socio-economic status of working age population (Social Trends 33, 2003)
** This will be dominated by overseas students and mature home students*

Socio-economic status	Accepted to JACS – Group ‘C’ Male	Female	All accepted	All applicants/accepted	Census 2001
Higher managerial and professional occupations	18.7	20.4	19.7	17.3/18.1	10.8
Intermediate occupations	11.9	13.5	12.9	12.1/12.2	10.3
Lower managerial and professional occupations	26.6	26.8	26.7	24.6/25.0	22.2
Lower supervisory and technical occupations	4.2	4.0	4.1	3.5/3.6	9.4
Routine occupations	4.8	4.7	4.7	4.5/4.4	13.3
Semi-routine occupations	10.0	10.1	10.0	9.9/9.8	9.8
Small employers and own account	5.8	5.8	5.8	5.7/5.7	7.7
Unknown*	18.1	14.8	16.1	22.4/21.2	16.5**
Total	10964	17584	28548	461365/368115	

*** Classified as long-term unemployed and those who have never worked. (Source: UCAS 2002-03)*

Ethnicity

The second area of interest relates to the ethnic composition of the student intake to the biosciences. As with socio-economic status, this will be reported to allow comparisons between: those accepted to the biological sciences subject group; those accepted to all degree programmes; and to population share.

Table 4.3: Ethnicity by gender

Ethnicity	Accepted JACS Group ‘C’ Male	Female	All accepted	Census 2001*
Asian - Bangladeshi	0.4	0.5	0.7	.5
Asian - Indian	1.8	2.8	3.8	1.8
Asian - Other	0.7	0.8	1.0	0.4
Asian - Pakistani	0.9	1.6	2.2	1.3
Asian - Chinese	0.7	0.5	0.9	0.4
Black - African	0.8	1.0	1.7	0.8
Black - Caribbean	0.6	1.0	0.9	1.0
Black - Other	0.2	0.2	0.2	0.2
Other Mixed	0.4	0.6	0.5	1.4
White and Asian	0.7	0.6	0.6	
White/Black African	0.2	0.2	0.2	
White/Black Caribbean	0.4	0.4	0.3	
Other	0.4	0.5	0.6	0.4
British	76.2	75.4	65.6	92.1
Irish	1.1	1.4	1.6	
Other White	1.1	1.3	1.5	
Not given=Home	8.5	5.4	7.9	
Not given=O/seas	5.0	5.8	9.9	

(Note: Some categories have been combined to match 2001 census data (Source: UCAS 2002-03))

As can be seen, for most ethnic minority groupings, the proportion accepted to higher education is greater than their share of the population; the exceptions being ‘Black – Caribbean’ and ‘Black – Other’. In addition, the greatest divergence from population share is exhibited by those from 'Asian – Indian' and 'Asian – Pakistani' ethnic groups and these groups also have a more marked gender imbalance in participation. For females, only 'Asian Chinese' and 'British' have a lower participation rate than males.

Age

In terms of age, Table 3.4 provides details of the age of all applicants accepting places in higher education in session 2002-2003. It is apparent that those accepting places on programmes classified JACS Subject Group 'C' are considerable younger than all those accepting places in higher education. This is true for both males and females.

Table 4.4 Age of all undergraduates accepting places in higher education

Age	JACS Group 'C' acceptances Male	Female	All degree acceptances
20 and under	83.3	85.4	77.8
21 – 24	9.8	6.8	11.7
25 – 39	5.8	6.4	8.5
40 plus	1.1	1.5	2.0

(Source: UCAS 2002-03)

Tariff scores

The final category in this section is concerned with the UCAS Tariff of those applying to and accepting places on degree programmes in the Biological Sciences.

Table 4.5 UCAS Tariff scores for those accepted on undergraduate programmes

UCAS Tariff Score	JACS Group 'C' acceptances Male	Female	All degree acceptances
0	22.9	17.3	27.0
1-79	3.9	2.4	3.3
80-119	3.5	2.3	3.6
120-179	9.9	5.9	8.1
180-239	14.1	10.9	11.1
240-299	15.4	15.7	12.8
300-359	12.6	17.2	12.2
360-419	8.7	13.6	9.6
420-479	4.9	8.4	6.1
480-539	2.6	4.2	3.6
540 +	1.7	2.0	2.6

(Source: UCAS 2002-03)

The data suggest that for both males and females the distribution of tariff scores is skewed. However the nature and direction of the skew is different. The distribution of the female tariff scores tends to be skewed to the top end of the scale, while male tariff scores tend to be skewed in the opposite direction. It would also appear that females with tariff scores of over 240 are more prevalent among those accepted to JACS Group 'C' than among those accepted on all programmes.

Destinations

One of the major sources of information regarding the destinations of undergraduates is provided by the 'First Destination Survey' compiled by HESA. Questions have been raised concerning the robustness of this data as a 'true' picture. Another source of destination data in the biosciences is provided by the Biochemical Society (2005) whose most recent survey is for 2003. Previous surveys are also available on their website.

Data is also available on the Centre for Biosciences (2005) website which provides information on a number of specific courses and these suggest that around 20 per cent of graduates go on to study for a research degree, a further 10 per cent enrol on a taught higher degree programme and around 5 per cent embark on some form of teacher training. At a more general level and covering more than one subject area, Prospects (2003) provides information on ‘Biology’ graduates and suggest that 12 per cent are studying for a higher degree and 5 per cent are studying a teaching qualification. Of the 55 per cent in employment, 10 per cent were employed in scientific R & D and a further 15 per cent employed in professional occupations.

The figures for the Biochemical Society feature a range of degree programmes. The criterion for selection is that course should contain at least 50 per cent Biochemistry although this is left to Heads of Department to decide. The list of subjects in the 2003 survey is available online and covers a range of single and joint honours programmes.

Table 4.6 Trends in Initial Employment (Source: Adapted from Biochemical Society, 2005)

Trends in initial employment of biochemistry graduates *Figures represent the percentage of total students entering the category of employment*							
	1990	**1993**	**1995**	**1996**	**1997**	**1998**	**1999**
After BSc							
Research training	34.3	33.1	30.5	31.1	31.0	33.7	32.3
Research in academia	5.2	3.4	3.4	2.9	3.5	2.4	2.8
Research in industry	5.4	4.4	7.5	6.5	7.7	8.1	7.9
Other science-based careers	7.9	6.1	8.3	8.9	10.0	8.4	13.1
School education	3.0	4.4	5.3	3.5	3.0	4.2	4.2
Total remaining in biochemistry	**55.8**	**51.4**	**55.0**	**52.9**	**55.2**	**56.8**	**60.3**
Other professional training or employment	16.2	14.6	15.2	18.3	18.2	20.6	19.9
Moved abroad	1.5	1.4	1.2	1.1	0.9	1.2	1.0
Unplaced, seeking employment	5.3	7.1	5.4	6.2	4.2	3.3	4.0

(Note: Figures do not add to 100% since overseas students, those unplaced but not seeking employment, and those of unknown destinations are excluded.)

The Biochemical Society provides data (Table 4.6) which illustrates trends in destinations over time. They suggest that throughout the 1980s and 1990s, the proportion of graduates remaining in biochemistry remained stable at between 50 and 60 per cent, with the proportion going on to further training reflecting a similar stability between 30 and 34 per cent. The proportion entering industry or other science based careers both increased through the 1990s. The proportion entering teaching has, according to the Biochemical Society, always been low although there has been a slight increase overall throughout the 1990s. The introduction of a ‘golden hello’ of £5000 in 1998 resulted in only a slight increase. The proportion of graduates moving outside science increased slowly throughout the 1990s but seems to have plateaued at around 20 per cent.

There have however been some changes since as evinced by data from the 2003 survey. There has been a slight decrease both in those continuing biochemical training (27.5%) and those remaining in biochemistry 51.0%). There was little change in the proportion entering industry (7.4%) while the popularity of teaching had dipped to three per cent. The proportion of those with Class 1 Honours going on to research degrees, was down from the 1990s and the increase in those with Class 2:2 entering the research pool suggests, according to the Biochemical Society, a lack of competition for places. Finally, the unemployment of all biological science graduates (6.5%) is slightly lower than that for graduates of all disciplines (7.0%).

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Appendix

CENTRE FOR HIGHER EDUCATION RESEARCH AND INFORMATION

Economic and Social Research Council: Teaching and Learning Research Programme (TLRP) - Phase III Research Project

What is learned at university? The social and organisational mediation of university learning (SOMUL)

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Project Summary

The aim of the project is to increase our understanding of the range of learning outcomes of an increasingly diverse higher education system. We are particularly interested in how these are socially and organisationally mediated. Social mediation refers primarily to the social mix of students and the characteristics of the student culture and lifestyle. Organisational mediation refers primarily to curriculum organisation (for example, the boundaries between different subjects and the links – formal and informal - between academic knowledge and workplace and other sources of knowledge).

The study will concentrate on students and graduates in three contrasting subjects – biochemistry, business studies and sociology. For each subject, five study programmes will be selected to represent the different social and organisational features in which the project is interested. Students from these programmes will be investigated at various stages during and following their undergraduate careers focusing on their conceptions of learning and personal and professional identity. The results will be set within the context of subject benchmark statements and programme specifications.

The wider applicability of findings from the initial three subjects will be assessed in relation to a further group of subjects, again taking a range of programmes with different social and organisational characteristics.

The project team will work closely with the new Higher Education Academy and with the Quality Assurance Agency for Higher Education in order to ensure close links with policy and practice. Employer inputs to the project will be secured through regular presentations to the policy forum of the Council for Industry and Higher Education.