

Review Essay

Linking Teaching and Research in the Biosciences

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Abstract

Research is so inextricably embedded within the teaching in the bioscience disciplines that many of us do not question that there is linkage between teaching and research – we simply know that it is true as part of our discipline culture. We, as bioscientists, have written this essay for the bioscience academic community. We start from the point of view that the link between research and teaching is embedded but not necessarily made explicit and that the link could be exploited more effectively for the benefit of staff and students.

We have attempted to articulate the development of understanding and skills of a bioscience undergraduate through the course of their degree. However, our main aim is to challenge bioscience colleagues to review and evaluate existing links and think about ways of developing and integrating new links into their teaching practice.

Keywords: teaching bioscience; linking teaching with research; case studies

Introduction

“Involving students in inquiry - in research - is a way of improving their learning, motivating them more. After all, what motivates large numbers of academics is engaging in the excitement of research. Bringing research and teaching together is a way of enhancing the motivation of both academics and students”
(Brew, in Jenkins et al, 2003).

“The Centre for Bioscience Advisory Group resolves that within its subject areas, integrating teaching and research is an essential component of undergraduate honours degrees. It is recognised that there will be institutional variation on how this is achieved. The Advisory Group further noted that the QAA Subject Benchmarks allude to these links. For instance, the subject knowledge section of the Biosciences benchmark states that all bioscience degree programmes will include:

“methods of acquiring, interpreting and analysing biological information with a critical understanding of the appropriate contexts for their use through the study of texts, original papers, reports and data sets”.

Similarly the Agriculture, Forestry, Agricultural Sciences, Food Sciences and Consumer Sciences Benchmark includes:

“integration of theory, experiment, investigation and fieldwork and the development of principles into practice”.

In addition, the resolution is in agreement with the qualification descriptors expected of an honours graduate (or equivalent) as outlined by the National Qualifications Frameworks”
(Bioscience Advisory Group resolution, 2003).

There is a growing amount of evidence to show that students may benefit from research activity, but for this to be maximised the linkage has to be explicitly planned and constructed (Jenkins *et al*, 2003). Recent reviews of current literature have stressed that:

- I. linkage between teaching and research is not automatic and has to be developed and managed (Jenkins *et al*, 2003);
- II. academic departments are central to developing the link (Jenkins and Zetter, 2003);
- III. there is little, if any, relationship between research productivity and teaching quality (Hattie and Marsh, 1996; Marsh and Hattie, 2002)

The focus of this essay is on undergraduate bioscience degrees. To maintain relevance we have concentrated on the issues from a UK higher education context and perspective. However, linking teaching and research is a topic of international research and debate (Jenkins *et al*, 2003). This essay forms part of a project entitled “Linking Teaching and Research in the Disciplines”, sponsored by the Generic Centre of the Learning and Teaching Support Network (now assimilated into the Higher Education Academy).

The relationship between teaching and research in the biosciences

The discipline is seen as an important factor in shaping the relationship between teaching and learning and the way in which the linkage is delivered by the curriculum is discipline dependent. For example: in a study of staff from English and Physics departments from two US universities, Colbeck (1998) found that the linkage was stronger with respect to the content of the curriculum in English. In Physics, the link lay more in the process of inquiry and the involvement of undergraduate and postgraduate students in staff research projects. What would the result have been if a similar study had looked at the biosciences?

Lindsay *et al* (2002) found that students studying disciplines such as our own (i.e. Bioscience) have more positive attitudes towards research than applied disciplines, such as business administration. It has been suggested that the reason for a more negative attitude in applied disciplines results from an inappropriately narrow conception of research (Jenkins *et al*, 1998).

The vast majority of academics in our discipline have a postgraduate qualification based on the execution of research project (typically a PhD). Also, most staff with teaching responsibilities are research active to some degree. As well as leading to the well-documented tensions between teaching and research for academic staff the amount of research going on in a department can have both positive and negative effects on students' views of a lecturer's research. Using the Research Assessment Exercise (RAE) as an indicator of the quantity of research in a department Lindsay *et al* (2002) found that the higher the RAE rating, the more positive the comments

students made about the way research affected their learning. For undergraduates, the number of negative comments also increased with RAE score. The interpretation of these results is that a high level of research activity increases student awareness of research and its impact upon teaching. However, the reduced access and availability of academics also becomes more evident as research activity increases (Jenkins *et al*, 2003).

The ease of involving students in research varies by subject because of the conceptual difficulty of current research in some disciplines. With a few notable exceptions, understanding what is going on in bioscience research is not conceptually difficult compared with physical sciences and mathematical disciplines. In contrast, the day-to-day technical knowledge and competence required to carry out practical research in the biosciences is considerable. Additionally, keeping up with a literature that is growing at an exponential rate is a major problem for all in the biosciences.

Above all, the bioscience disciplines are experimental sciences and their defining characteristics are:

- that all knowledge is related to observation or experiment
- a family of methods and disciplines grouped around the investigation of life processes and the interrelationships of living organisms
- they exist in an environment of current hypotheses rather than certainty
- they include disciplines in which rapid change is happening
- they are essentially practical and experimental subjects

The importance placed upon the integration of teaching and research in biosciences degrees is strongly reflected in the benchmark statements for Bioscience and for Agriculture, Forestry, Agricultural Sciences, Food Sciences and Consumer Sciences (see Appendix 1).

The development of understanding and skills of a bioscience undergraduate through the course of their degree programme

We have found that the 'aspects and ways of thinking and practising in biology' model developed by Hounsell and McCune (2002) provides a useful framework for articulating the development of understanding and skills of a bioscience undergraduate through the course of their degree (Figure 1).

Two interrelated aspects of ways of thinking and practising in Bioscience are identified by Hounsell and McCune: *forms of understanding* and *a range of skills and competences*. Each of these aspects has two levels, a basic level of mastery of the fundamentals and a higher order capacity which grows out of the fundamental building blocks and extends beyond them.

The relationship between these in terms of how the subject is taught to undergraduates may be put in context of what happens in a typical undergraduate bioscience course (mostly three-year in England and Wales, and years 2–4 in the four-year courses of Scotland and Northern Ireland).

In **Year 1** much of the foundation information is taught along with background material in, for example, chemistry, data handling and IT skills, or statistics. At the end of the first year the student should become familiar with the “vocabulary” of the particular subject area. Textbooks are important in ‘backing up’ the foundation information transmitted in face-to-face teaching. As well as being a source of factual information, they offer an introduction to the scientific method by describing ‘classic’ experiments and how they facilitated paradigm shifts in understanding. In practical classes in the laboratory or the field, students will see and use simple equipment, make measurements and observations. There will be an opportunity to interpret data, but realistically the experiments tend to be ‘rote’ with known outcomes. The majority of students are more concerned with operating successfully in the laboratory and achieving what they believe to be the ‘right’ result. In seminars they will talk about science, do small problems, and perhaps have to partake in activities such as producing a poster or explaining a simple diagram or graph to the rest of the class.

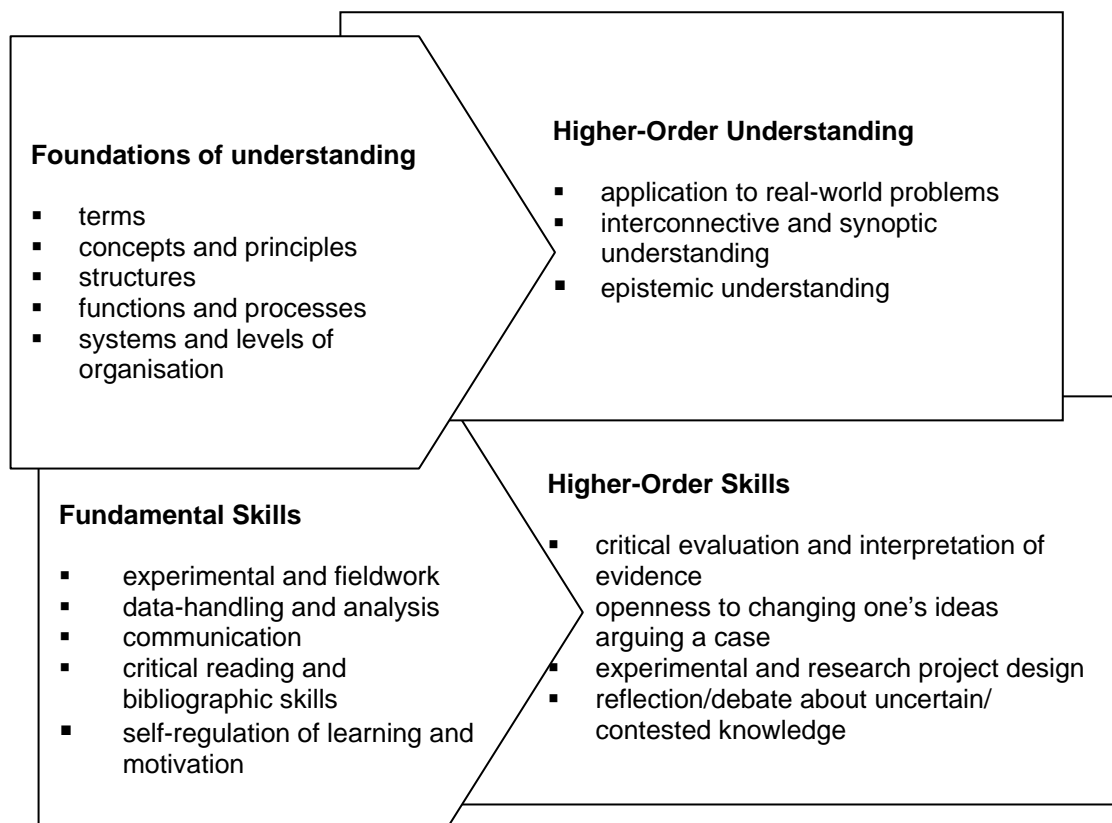


Figure 1 Aspects of ways and thinking and practicing in biology (reproduced from the web document of Hounsell & McCune, 2002)

In **Year 2** foundation material continues to be taught but students will start looking beyond their textbooks to the primary scientific literature. They will also be expected to understand how to find things in the literature. They will be introduced to the idea of criticism and controversy. The practical classes will be more ‘open-ended’ and will require an element of planning beforehand in order to design the protocols and choose appropriate controls.

In **Year 3** the lectures will be on up to date topics, there will be a degree of specialisation and choice, and there will probably be small classes when recent literature papers are examined, discussed and criticised. Some departments claim to do their teaching in the final year “based on the current research literature”.

Projects are a feature of final-year work and the research project experience is enshrined in the benchmark statements as an almost mandatory requirement for any student graduating with a bioscience degree (Appendix 1). During the project the student will plan, carry out and interpret experiments, and communicate and defend their findings in a scientific manner. It is not just the science and the way of doing science that is important here. The social environment of the laboratory and the relationships between students, supervisors and the rest of the research group are also important for student’s motivation and engagement, and ultimately, their understanding of the process of science in the real world. In order to learn how science is done students need to experience an atmosphere that values the research method and encourages criticism and controversy as a major way that science develops. This can be very uncomfortable for the student who works at the surface level, learning in order to regurgitate in the examination, but even good students can have difficulties in understanding the nature of scientific enquiry. The change from the ‘cookbook’ approach in the early years of a course to the project is highly significant and completely transforms the students’ view of how science research works (Ryder and Leach, 1999).

Bioscience departments have developed strategies to progress students from the foundations of understanding and fundamental skills (years 1 and 2) to higher-order understanding and higher-order skills (years 2 and 3, with the main focus on the research project). The first years of laboratory or fieldwork obviously include learning technical skills in using equipment and recording data as well as in data handling. However, the environment in which students do laboratory or fieldwork should change from being rote exercises to encouraging their understanding of why this work is being done. The words and phrases relating to higher-order understanding and higher-order skills are those connected with research – application of understanding to real-world problems, critical evaluation and interpretation of evidence, arguing a case debate etc. This involves understanding that the outcome of research rests on an interpretation of data and an admission that the ‘facts’ may not be certain and may change in the light of further investigation. Students engaged in the actual practice of research start to see that things are never perfect and the results of an investigation are dependent upon an interpretation of what has been observed.

Hounsell and McCune (2002) record conversations with individuals teaching in Bioscience departments that reveal their strategies. Thus:

In my third year module, I work very much from a literature interpretation viewpoint and regard that as the pinnacle of knowledge for an undergraduate biologist. [NOTE undergraduate, our emphasis] That is, not knowing a huge

amount of biology but rather knowing how to read scientific journals and make sense of them and interpret the information.

Another emphasised:

. . . the importance of developing critical faculties in terms of looking at experimental evidence and its interpretation: teaching them to be open to changing ideas as more and more evidence accumulates.

The final-year research project is the time at when learning experiences are most intense, and students really discover what it is like to do research in the bioscience disciplines. This highly prized learning experience is dependent on a developmental curriculum design that allows students to evolve their grasp of the subject over the period of their degree.

Students who take advantage of a year out working in industry or in a research laboratory, often abroad, tend to have an even more intense experience of research in the “real world”, and many students in the biosciences now do this placement. Some universities aim at two six-month placements, but most expect students to take the whole year out before their final year. Those working in an industrial laboratory also gain experience of ‘Good Laboratory Practice’ and issues about confidentiality. The majority of students doing placement return to their courses with a greatly increased intellectual maturity.

In the above section we described what happens and how bioscience undergraduates progress through their degree programme in a developmental way so that at the end that they are able to fully engage with real research. The final-year project is a critical area for linking staff research and student learning (Ryder, 2004). Discussions on how this immensely important part of the student experience can continue to be provided to all students is one focus of discussion by the Centre for Bioscience Special Interest Group: Final Year Project work in the Biosciences

(<http://www.bioscience.heacademy.ac.uk/network/sigs/project/>)

How are teaching and research linked in the biosciences?

There are (at least) two reasons for this section of the essay (1) to review and evaluate existing links – you may use these activities in your teaching already but never have explicitly articulated for yourself or colleagues that they are based on linking teaching and research; and (2) prompt you to think about ways of developing and integrating new links into your teaching practice. We have nominally placed case studies under particular headings based on the Jenkins and Zetter's strategies for linking teaching and research at the level of the module/course (Appendix 2). However, many of the case studies could appear under more than one heading as they address multiple strategies. It may appear at first glance that some of the activities/outputs described in the case studies are very similar in nature i.e. producing a student journal (see Case Studies by Potter (No. 4); and Knight, No. 12) we have included them because the problem being addressed/desired outcomes are different.

Developing students' understanding of the role of research in their discipline

The basis for the following is the assertion of Jenkins *et al* (2003) that university education is about inducting and developing students into a view of knowledge as changing through the process of enquiry.

How can we help students develop a view of knowledge as being created, uncertain and contested, particularly in the first and second years of their degree? As we have already discussed much of the early learning is based on collection of 'facts' from textbooks and 'rote' or 'cookery' practicals.

To move forward we need to consider the form that research takes in our particular discipline within the biosciences – the extent to which research is individual or team based and how it is funded and organised. There is a wide variation in 'how research is done' in the biosciences from individuals spending months in the field working on their own to a lab-based team working within the same research area. Increasingly, research in the biosciences is set in multidisciplinary – context in which the field is moving rapidly and knowledge increasing exponentially – this a major challenge in training the next generation of bioscience researchers. This being said there is little difference in the philosophy.

The majority of bioscience undergraduate courses have a core curriculum covering the fundamentals of biology. Lecture courses and textbooks often start at first principles and build up to current state of knowledge through the 'story' of key experiments/findings backed up by practicals replicating the experiments. Thus the first year curriculum brings out, incrementally, the way core concepts, knowledge and practices of the discipline have developed through research. Thus, in contrast to many of the issues raised, problems may arise during the second year when students have far more module choices available to them. Clear guidance for students in choosing an appropriate curriculum and for staff in developing programmes of study will help maintain this. The following case studies illustrate some methods for developing students' understanding of the role of research in bioscience disciplines:

Managing the student experience of staff research

The authors have found difficulty in identifying examples, within the bioscience disciplines, of limiting the negative consequences of staff research for students. A regularly quoted example is from the Geography Department at University College London (UCL). The UCL course team required first-year students in tutorial groups to interview a member of staff about the development of their research, and their views on research directions in the discipline, and then to write an analysis of the interview (Dwyer, 2001).

The following case studies illustrate some methods for supporting students in making clear to them the employability elements of research:

CASE STUDY 1

Taking learning into the field (Park, 2002)

This core first year module is designed to introduce students to basic research techniques and research issues associated with Rural Environmental Sciences using existing research projects and themes in the School and via field visits to local research institutions. This concept is underpinned by the high research rating (score of 5 in the RAE) of the School of Agriculture, Policy and Development from which the degree is co-ordinated, the availability of on-going research projects and the geographic position of the University which provides access to a number of high quality research institutes relevant to the degree subject. The actual background to activities that a given cohort of students pursues changes as different research projects are completed and new contracts won. This gives a dynamic background to the module which ensures students are being associated with the latest research projects. To develop students understanding of field experimentation, monitoring and lab techniques via research within the university and at other local institutions. Additionally the module aims to provide students with the knowledge of the career opportunities that are available to them.

Park J. (2002) Taking learning into the field. Linking Teaching and Research in the Biosciences Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

CASE STUDY 2

Producing a research proposal, paper and presentation (Davies, 2002)

The module simulates a real research project based on a five-day residential field trip to a working marine station where typical laboratory materials are available. By the end of this module the students have gained experience in all the stages of managing and executing an independent marine field study, from the initial formulation of the idea for the study and application for funds, right through to formulating and communicating the results, both orally and in a written scientific paper.

Davies, M. (2003) Producing a research proposal, paper and presentation. Real-World Project Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/realworld.htm> [accessed 21 January 2005]

CASE STUDY 3

Research is competitive – working as 'internationally renowned research scientists' (Assender, 2004)

To engender a sense of fun, competition and hence greater interest in a four-week practical investigating the quaternary structure of haemoglobin, the practical was introduced by telling the students that they were to imagine that they are not students in a Level 2 lab, but rather a team of research scientists working in an internationally renowned laboratory on the quaternary structure of a novel protein. They suspect that other groups have found a similar protein and you want to publish your results at a forthcoming international conference and get recognised as the group that first came up with the definite structure. Each team has an identity as the team from a particular country and they are referred to as the representatives of that country over the next 4 weeks.

Assender, J. (2004) Research is competitive - working as 'internationally renowned research scientists. Linking Teaching and Research in the Biosciences Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

CASE STUDY 4

Publishing undergraduate research in an extra-curricula house journal (Potter, 2002)

Origin is an undergraduate journal, devised to offer a genuine experience of research publication to students in response to a perceived need as a significant proportion of students go on to further discipline-specific study or research when their degree is completed. Publication does not accrue academic credit. The benefits of publication to the student are considered to be the genuine experience of completing the full research cycle and the end product, a professionally produced article, which student authors can include with their curriculum vitae. Feedback from student authors also indicates that they gain a great deal of personal satisfaction and learn a great deal about scientific writing and the research and publication process.

Potter, J. (2002) Origin: publishing undergraduate research in an extra-curricula house journal. Linking Teaching and Research in the Biosciences Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

Developing students' ability to carry out research in their discipline

There are many examples of how bioscience curricula have integrated activities to develop students' ability to carry out research. However, it may be appropriate to audit and review practice at the course/programme level to ensure that research methods are taught and practiced, and development is progressive rather than repetitive. Are a variety of approaches /skills/methods delivered?

The following case studies illustrate some methods for developing students' abilities to carry out research in their discipline:

CASE STUDY 5

Introducing undergraduate students to scientific reports (Willmott *et al*, 2003)

A series of exercises are undertaken with Level 1 students as introductory training towards the reading and presentation of scientific papers. In the first exercise, students consider the structure of a scientific report and read and evaluate a given research paper. Subsequently, students are asked to imagine themselves as scientific investigators interested in a specific problem. In tutor-led group discussion, they design an experiment to investigate the problem and then individually write a report based on provided data.

Willmott, C.J.R., Clark, R. P. & Harrison, T. M. (2003) Introducing undergraduate students to scientific reports. Bioscience Education E-journal Volume 1 available at <http://www.bioscience.heacademy.ac.uk/journal/vol1/beej-1-10.htm> [accessed 21 January 2005]

CASE STUDY 6

Research skills training for undergraduate researchers: the STARS project (Finn and Crook, 2003)

The Scientific Training by Assignment for Research Students (STARS) project (<http://www.ucc.ie/research/stars/>) comprises of an internet-based learning resource that has been designed to help undergraduate students develop a number of fundamental skills associated with conducting scientific research. In particular, it aims to improve the ability of students to plan, design, manage and execute scientific research whilst providing opportunities for formative assessment and rapid feedback.

Finn, J. and Crook, A. (2003) Research skills training for undergraduate researchers: the pedagogical approach of the STARS project. Bioscience Education E-journal Volume 2 available at <http://www.bioscience.heacademy.ac.uk/journal/vol2/beej-2-1.htm> [accessed 21 January 2005]

CASE STUDY 7

Teaching experimental design using research based examples (Hughes, 2002)

This day-long teaching session prepares students to design their own experiments in lab classes and research projects. The day begins with a lecture on the principles of experimental design and an exercise in producing a written experimental design, and in the afternoon they produce a written experimental design which will be assessed. The students are told to consider the problem, using a heading for each point of design which they consider, and outline the issues they discussed and the conclusion they came to in producing a written experimental design. This latter will be assessed. Following this, the lecturer then unpicks the actual design process which they went through before carrying out the work, or each successive piece of work in a series. This includes the thought processes and, most importantly, where in retrospect the design was poor. The background to the problem is explained along with real-life constraints which caused a perhaps less than ideal design to be used. The actual outcomes (results) are detailed and the lessons learned. The groups assess their own experimental design against a marking schedule.

Hughes, I. E. (2002) Teaching experimental design using research based examples. Linking Teaching and Research in the Biosciences Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

CASE STUDY 8

Data analysis task using data from a collaborating organisation (Murphy, 2002)

The 'Research Methods and Data Analysis' module sparks interest and motivation in MSc students by involving local organisations in the provision and presentation of data. The intention is to involve students with a real organisation, identifying real problems and issues, analysing real data and producing valuable results.

From several possibilities, we chose an enthusiastic partner from a local health organisation who offered a large volume of health data relating to breathing disorders. The data was anonymous so that there was no problem with confidentiality.

Murphy, R. (2002) Data analysis task using data from a collaborating organisation. Real-World Project Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/realworld.htm> [accessed 21 January 2005]

CASE STUDY 9

Group project work on Biological Clocks (Cogdell, 2004)

The module is built around a need to provide more group work to develop team working and communication skills. The subject-related aim of the module is to enable students to appreciate a biological phenomenon across the spectrum of biology from the molecular to the behavioural. It also aims to introduce students to the human relevance and commercial applications of the study of biological rhythms.

The module consists of lectures for the first five weeks followed immediately by the course exam. The remainder of the module is spent doing a group project where the students carry out an experimental investigation. This encourages the understanding of experimental design, both in terms of implementation and flaws. Specifically the students are instructed to find and measure, and if appropriate alter, a biological rhythm in any life form they choose. The project outcome is to produce a poster of their results.

Cogdell, B. (2004) Group project work on Biological Clocks. Linking Teaching and Research in the Biosciences Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

CASE STUDY 10

Writing and reviewing an article for a scientific magazine – a peer/self assessment exercise (Reed, 2004)

The exercise forms part of a Level 2 module in research methods and scientific communication, taught to classes of 60-90 bioscience students. Students can find such topics rather dry and, as a result, the taught sessions rely heavily on workbooks and worksheets to cover the syllabus, which includes: locating and evaluating sources; primary and secondary literature; style and layout; the peer review system and its role in scientific publication; citation and referencing. The assignment requires students to apply the knowledge they have gained in the taught sessions to a short exercise, to satisfy the following learning outcomes:

Use relevant methods to locate and interpret research information in the primary scientific literature;

Use appropriate forms of scientific communication, in this module and in other modules within the programme.

Reed, R. (2004) Writing and reviewing an article for a scientific magazine - a peer/self assessment exercise. Linking Teaching and Research in the Biosciences Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

CASE STUDY 11**Mini-conference: Student Oral Presentations in a Real World Setting (Worsley, 2002)**

The module begins with introductory formal lectures and one or two full-day field visits to the Sefton Coast on Merseyside. The students then embark on research projects of their own design based on coastal studies with a distinctly regional flavour. The students work in small research groups and liaise closely with organisations, researchers, land managers and users of the coast in Sefton. As they collect data and develop their research activity, they also help to prepare for and organise a one-day mini-conference. This is an opportunity for them to present their findings alongside guest speakers.

Worsley, A. (2002) Mini-conference: Student Oral Presentations in a Real World Setting. Real-World Project Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/realworld.htm> [accessed 21 January 2005]

Privilege: research opportunities to selected students

Final-year research projects are a feature of almost all biosciences undergraduate courses. Ryder (2004) presents a characterisation of student learning on 'traditional' final year research projects and asks to what extent alternative teaching activities can achieve an equivalent learning experience. In a climate of increasing student numbers there is growing interest in providing alternatives to such resource-intensive projects. The alternatives can be as rigorous and challenging as the traditional lab- or field- based project but are viewed by the majority as being 'second-best'. Is ring-fencing the 'real thing' for high achievers and/or for students who have already decided to pursue a research career the right approach?

CASE STUDY 12**Establishment of an undergraduate research e-journal (Knight, 2004)**

Biolog-e is an undergraduate student e-journal based upon assessed final year research projects. The e-journal is used as an example to undergraduates of how research results are disseminated and of the standards required for research careers. Only research projects that receive a first class mark are published in the journal: this rewards good student performance and informs students who have yet to embark on final year projects of the standard to which they should be aspiring.

Knight, C. (2002) Establishment of an undergraduate research e-journal. Linking Teaching and Research in the Biosciences Case Study available from <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

CASE STUDY 13

Bringing home the swampiness of life (Brennan *et al*, 2004)

This exercise uses the basis of a particular Knowledge Transfer Partnership (KTP, previously Teaching Company Scheme) to develop a specific case study each year. Each case study focuses on a small problem within the larger two to three year KTP project. As such, the project tends to be a blend of practical use of food technology pilot plant equipment, and also deals with the background theoretical research. Students are allowed to organise their work pattern in order to meet the objectives of the particular project.

Brennan, C., Folland, E., Preston, R. and Blatchford, N. (2004) Bringing home the swampiness of life: the use of peer-assessed problem-based case studies within food science and technology by the integration of industry sponsored technology transfer projects into student learning. Linking Teaching and Research in the Biosciences Case Study available at <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

CASE STUDY 14

A student-organised conference (Sparagano, 2004)

Almost all our graduate students do not continue a career in parasitology so was little need for discipline related skills training. However, there was a need to give our students more experience and training in transferable skills to respond to the expectations of potential graduates' employers. There were few opportunities for interaction between the students and non-academic professionals.

In order to address the above issues, a new format for the Level 3 parasitology module was adopted: a peer assessed, student-organised conference and the introduction of a variety of assessed tasks. Employers were invited to attend and assess the students.

Sparagano, O. (2004) A student organised conference. Linking Teaching and Research in the Biosciences Case Study available from <http://www.bioscience.heacademy.ac.uk/projects/ltr/> [accessed 21 January 2005]

For more examples of how bioscience practitioners have brought research and teaching to enrich the undergraduate experience access the Case Studies and annotated bibliography on 'Linking Teaching and Research' in the Bioscience Centre's site (<http://www.bioscience.heacademy.ac.uk/projects/ltr/>)

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Ryder, J. and Leach, J. (1999) University science students' experiences of investigative project work and their images of science. *International Journal of Science Education*, **21** (9), 945 – 956

Appendix 1 The QAA Biosciences Benchmark Statements (2000)

QAA stands for the 'Quality Assurance Agency for Higher Education' which was set up in 1997 to ensure that the quality of education was satisfactory, to encourage improvements, and to publish reports providing public information on the quality of higher education in England and Northern Ireland. The extracts given here are those relevant to Linking Teaching and Research.

Bioscience Benchmark Statement (Extracts relevant to Linking Teaching and Research*)

3.2 Subject knowledge

Methods of acquiring, interpreting and analysing biological information with a critical understanding of the appropriate contexts for their use through the study of texts, original papers, reports and data sets.

3.3 Generic skills

The ability to read and use appropriate literature with a full and critical understanding while addressing such questions as content, context, aims, objectives. Quality of information, and its interpretation and application.

[The ability to employ a variety of methods of study in investigating, recording and analysing material.]

3.6 Practical skills

Designing, planning, conducting and reporting on investigations which may involve primary or secondary data.

Obtaining, recording, collating and analysing data using appropriate techniques in the field and/or laboratory.

Undertaking field and/or laboratory investigations of living systems in a responsible, safe and ethical manner.

3.7 Numeracy, communication and IT skills

Sample selecting; recording and analysing data in the field and/or the laboratory; validity, accuracy, calibration, precision, replicability and uncertainty during collection.

Preparing, processing, interpreting and presenting data, using appropriate qualitative and quantitative techniques, statistical programmes, spreadsheets and programs for presenting data visually.

4.3 Teaching, learning and assessment

Lectures should encourage and enable students to . . . understand the means by which scientific information is obtained.

4.4 Teaching, learning and assessment

Laboratory classes, fieldwork and computer sessions provide education in scientific approaches to discovery, practical experience, opportunities for acquisition of subject-specific and transferable skills.

4.6 Teaching, learning and assessment

All honours degree students are expected to have some personal experience of the approach, practice and evaluation of scientific research (e.g. within a project or research-based assignments). This is likely to be in a student's final year.

Generic standards

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.

Subject-specific standards (molecular aspects)

Be able to devise and evaluate suitable experimental methods for the investigation of relevant areas of biochemistry and molecular biology.

Agriculture, Forestry, Agricultural Sciences, Food Sciences and Consumer Sciences Benchmark Statement (Extracts relevant to Linking Teaching and Research*)

3 Subject knowledge and understanding

3.4 Integration of theory, experiment, investigation and fieldwork and the development of principles into practice; quantitative and qualitative approaches to information.

4 Abilities and skills

4.1 Plan and execute research or development work, evaluate the outcomes and draw valid conclusions.

4.4 *Intellectual skills*: design an experiment, investigation or survey or other means to test a hypothesis or proposition; critically analyse information, synthesise and summarise outcomes.

4.5 *Practical skills*: plan, conduct and report on investigations including the use of secondary data; collect and record information or data in the library, laboratory or field, and summarise it using appropriate qualitative and/or quantitative techniques; devise, plan and undertake field and laboratory investigations in a responsible and safe manner.

4.6 *Numeracy skills*: appreciate issues of sample selection, accuracy, precision and uncertainty during collection, recording and analysis of data in the field and laboratory; prepare, process, interpret and present data using appropriate qualitative and quantitative techniques and packages.

5 Teaching, learning and assessment

Programmes will contain practical classes inside and outside the laboratory; literature-based research, case studies, problem solving.

* Note that some of the wording has been changed slightly from the continuous mode, i.e. "plan and conduct" rather than "planning and conducting", and that under "Performance levels" a digest has been produced of the wording in the three levels specified [threshold, typical and excellent]

Performance levels in practical skills expected

Plan, conduct and present an independent investigation; use appropriate laboratory and field equipment safely; select and apply a range of methods to solve problems; describe and record accurately in the field and laboratory; interpret practical results; present results/research finding in a number of formats.

Appendix 2: Strategies for linking teaching and research at the level of the module/course (see Jenkins and Zetter, 2003)

Develop students' understanding of the role of research in their discipline

Develop the curriculum to bring out current or previous research developments in the discipline

Develop the curriculum to bring out, incrementally, the way the core concepts, knowledge and practices of the discipline have developed through research

Develop student awareness of learning from staff involvement in research

Develop student understanding of how research is organised, commissioned and funded in the discipline/institution

Develop students' abilities to carry out research in their discipline

Develop the curriculum, in particular how students' learn, in ways that mirror or support the research processes in the discipline

Assess students in ways that mirror or support the research processes in the discipline.

Provider training in relevant research/skills/knowledge

Develop student involvement in staff research by inviting students to staff seminars

Re-run research projects as teaching and learning tools for students to validate research design, methods, data sets and to rework analysis and reporting

Critique staff publications from research perspective; ask students to design their own methodology

Provide students with a dissertation topic list which, appropriate to their level of study, interacts with current staff research projects

Ask staff to present their research in research methods courses in terms of 'how did you research this issue?'; 'what were the problems?'. Ask students to critique the approach.

Ensure that the dissertation component of a degree is supported by a research training tool kit clearly articulated and embedded form preceding course modules/units.

Privilege research opportunities to selected students

In the USA, which has long operated a mass higher education system, student involvement in research with staff is mainly or only offered to those with high grades/motivation.

Manage student experience of staff research

Limit the negative consequences for students of staff involvement in research. Most important here is managing the student experience of the days (and sabbatical terms) when staff are away doing research. At a minimum, students need clear information as to when staff are available

Evaluate/ research the student experience of research and feed that back into the curriculum

Support students in making clear to them the employability elements of research