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Teaching-Learning Environments in Undergraduate Biology: Initial Perspectives and Findings

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T·L·R·P Teaching & Learning Research Programme
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1. INTRODUCTION

1.1 Background

This report gives an overview of the findings relating to biology from the first year of the ETL project. The project has been running since January 2001 and will end in December 2004; it is funded by the Economic and Social Research Council in the UK under its Teaching and Learning Research Programme. The project as a whole aims to enhance the quality of learning achieved by students in higher education by working with academic colleagues to develop the teaching and learning environments provided in their course units. The intention from this work is to increase the sector wide capacity for evidence-based practice in relation to teaching and learning. Most previous research in this area has not fully addressed disciplinary differences, so one of the aims of the ETL project is to provide subject-specific perspectives on teaching and learning in five areas: biological sciences; economics; electronic engineering; history; and communications, culture and media.

Within the biological sciences, the main focus is on molecular and cell biology and the intention in the present report is to provide initial perspectives on undergraduate teaching and learning in that area which will inform the later stages of the research. In biology, as in all five subject areas, one component of the first phase of the project was a survey of a representative range of teaching quality assessment reports from eight highly rated departments. The reports reviewed organismal as well as cell and molecular provision and were chosen so as to be broadly representative of the range of institutions currently offering undergraduate-level courses in the area. Subsequently, telephone interviews were carried out with staff from four highly rated departments, focusing on the area of molecular and cell biology. It is these interviews which form the main basis of the analysis presented in this report. Ongoing discussions with our subject advisor, together with a review of the literature, have informed the analysis and interpretation of those findings.

The second phase of the project, which began in January 2002, will involve around six molecular and cell biology course units across three different institutions. The focus of this work will initially be on exploring the nature of high-quality learning in these settings and the ways in which that learning is exemplified, promoted or hindered. As the second phase progresses, and drawing on the evidence gathered, the project team will collaborate with colleagues in the target settings to introduce and monitor the impact of a modification to the teaching-learning environment intended to further strengthen the achievement of high-quality learning. Throughout this phase we will also be refining and reporting how we work with colleagues on these issues. Thus far, we have completed the first round of data collection in a first year course in one of the institutions involved in the second phase. We are now in the process of analysing that data with a view to negotiating some modification to the course unit in the coming academic year, which we will then monitor. We have also negotiated access to a final year course in that institution, and have agreed the involvement of the other two institutions. Data collection in these new settings will also begin in the coming academic year. This report is intended to inform the next stages of this work.

1.2 The present report

The report is in four parts. Following this opening section, the second part of the report presents a review of the literature relating to undergraduate teaching and learning in the biosciences, while also introducing perspectives from the more general literature on learning and teaching in higher education which have particular significance for the work of the project. The third part of the report describes the telephone interviews which were undertaken with a small sample of biology teachers and discusses the resulting findings. Finally, it reviews the implications of the literature review and interview findings for the next phase of the project's work.

2. REVIEW OF THE LITERATURE

2.1 The current context of teaching and learning in the biosciences

In order to carry out the work of phase two effectively, it will be crucial to be alert to the broad contextual factors which might affect teaching and learning in our target departments. This section of the report attempts a preliminary mapping of those factors; it will only be during the ongoing research for phase two that we discover their full implications. Across UK higher education as a whole, the most dramatic changes in recent years have been to do with a very substantial growth in the numbers of students entering higher education, the increasing diversity of their backgrounds, and the lack of a commensurate increase in staff numbers to deal with that influx (Dearing Report, NCIHE, 1997). One consequence has been a recasting of teaching-learning strategies and assessment procedures to respond to the challenge of teaching larger classes with reduced resources (Gibbs and Jenkins, 1992). Modularisation has also had a marked effect on teaching and learning in many institutions, as has the increasing use of technology for both teaching, assessment and organisational purposes (Dearing Report, NCIHE, 1997; MacFarlane Report, CSUP, 1992) Paralleling all of these changes has been a marked shift towards greater diversity in forms and methods of assessment (Gibbs, 1995; Hounsell et al., 1996). The impact of Advanced Highers and Curriculum 2000 on students' preparedness for courses in higher education will also be an important issue over the time span of the ETL project.

There will be a range of different pressures on staff in higher education over the course of the project. Both benchmarking and the new quality assessment procedures will have an impact, but it is not yet clear what that might be. In many subjects, including the biosciences, both professional bodies and employers have a legitimate and growing interest in what and how students are taught. Discussion at a recent meeting of the Learning and Teaching Support Network for the Biosciences made the complexity of these issues clear; different types of employers seem to want quite different skills from graduates. As participation in higher education becomes more costly for students and their parents, both of these groups may directly or indirectly put more pressure on staff as they seek to get 'value for money'. Although the Research Assessment Exercise has just finished, research productivity will continue to be a key issue for many staff.

As far as the molecular biosciences in particular are concerned, the subject overview in England and Northern Ireland, and the ratings reported by the Scottish Higher Education Funding Council suggest a generally positive picture of teaching and learning in this area. One area in which problems were identified, however, was in giving appropriate feedback to students on their assessed work (Quality Assurance Agency, 2000). The QAA also identified problems in supporting students in developing their generic skills, a theme which perhaps becomes more important as a smaller proportion of biosciences students go on to work directly in the discipline. Many of these skills, however, will also be relevant for students who do go on to work in the biosciences. Skills in communicating to non-scientists, for example, seem important given the recent media focus on issues such as BSE, genetic modification of plants and animals, and the use of embryonic stem cells in research. There is also a more general concern about public distrust of scientists (Blakemore, 2000). Indeed, as the interdependency between science and public life increases, this may also suggest the need for more attention to be given to ethical education for students of the life sciences (Clarkeburn, Downie and Matthew, 2002).

Another key theme in molecular and cell biology is the extremely rapid pace at which knowledge is currently developing. This means that curricula and teaching methods have to evolve continually (van Heyningen, personal communication; Wood, 2001). For example, there has been an explosion of knowledge recently in the area of bioinformatics, which involves the use of computers to analyse large data sets, such as those arising from the human genome project (Attwood, 2001; Wood, 2001). These changes have led to problems attracting suitably qualified staff who can teach in this area. There is some debate about the extent to which bioinformatics should be taught at undergraduate level, but nonetheless computing, mathematics and statistical skill are becoming increasingly important for biosciences students and mathematical skill in particular has traditionally been a problem for this group (Milner-White, 2001). This rapid pace of change also has implications for the cost of teaching in the biosciences as students need access to the most up to date literature and IT sources (Long, personal communication) in a period when, as we have already noted, unit funding has declined while student numbers have grown rapidly.

Issues of cost and the rapid expansion of knowledge in the subject are especially pertinent to laboratory classes and project work in the biological sciences; laboratory work may be cut back both to allow time to cover new content or to cut costs (Jones and Weyers, 2001). These issues have led some biologists to question the value of continuing with traditional practical and project provision for all students, given that many of them now go on to careers which do not involve laboratory work (Jervis, 1999). Alternatively, it can be argued that students who go on to careers such as science journalism have more need of laboratory work as undergraduates, since they need to understand 'how science is done', but may not get the opportunity to experience this first-hand in their careers. This assumes, however, that laboratory and project work done by undergraduates can offer a good representation of the work of professional scientists. This is an issue because modern molecular and cell biology work can require equipment and time scales that would be unrealistic in undergraduate contexts, as illustrated in this comment from one of our telephone interviews [see pp. 13ff. below]:

> *extract 1*
>
> … I think the problem with practicals is that they are so far removed now from what real practical biology is like and they have to be because you couldn't do real practical biology on the sort of scale and time scale that you need for undergraduate labs ...

The situation is further complicated by the likelihood that, if lab work were to be significantly reduced for some students, funding would probably decrease, perhaps making it more difficult to maintain high-quality resources for those students who are seen to need them (Jervis, 1999). Raising these questions about the value of laboratory work has led some authors to both debate the main purposes of laboratory and project work, and to suggest adaptations or alternatives to some parts of that work, including the use of computer-assisted learning packages (CAL) (Hodson and Bencze, 1998; Jervis, 1999; Jones and Weyers, 2001; Kirschner and Huisman, 1998; Séré, 1998; Wood, 1996).

Creating alternatives to practical work is just one of the areas in which the use of information and computer technologies (ICT) impacts on teaching and learning in the biosciences (Kirschner and Huisman, 1998). Other key issues include the development of the field of bioinformatics and the use of computer-based assessments (O'Hare, 2001). Virtual and managed learning environments are increasingly being used to organise and support teaching and learning, but little is yet known about the effect of such initiatives on students' experiences of learning in the biosciences. The impact of all of these developments over the course of the ETL project will depend partly on practical considerations, including the cost and time involved in developing packages and updating them to keep up with changes in the underlying platforms.

2.2 High-quality learning and ways of thinking and practising

One of the key foci of the ETL project is the nature of high-quality learning in the five subject areas and the ways in which that learning can be exemplified. The definition of high-quality learning in each subject area will necessarily evolve throughout the project, but in the initial proposal, high-quality learning was defined, firstly, in terms of students' approaches to learning and studying and their engagement with their studies. The approaches are descriptions of different ways of learning and studying which have been developed through more than twenty-five years of qualitative and quantitative research with students across a range of contexts (Biggs, 1987, 1999; Entwistle, 1997, 1998a, 2000; Entwistle and McCune, under review; Entwistle and Ramsden, 1983; Marton and Säljö, 1976, 1997; Tait, Entwistle and McCune, 1998). A summary of the approaches, as they are currently being conceptualised within the project, is given in Table 1. The deep approach, allied to organisation and effort, and monitoring studying, describes a combination of cognitive processes, motivation and engagement which provides a proxy for some of the kinds of learning that we would expect students to use in higher education.

Table 1: Aspects of approaches to learning and studying
(Based partly on Entwistle, 1997 p 19)

Deep approach
The intention to understand ideas for yourself
Making links between topics
Relating what is learned to the wider world
Looking for patterns and underlying principles
Checking evidence and relating it to conclusions
Examining logic and argument cautiously and critically
Becoming actively interested in the course content

Surface approach
The intention to cope minimally with course requirements
Studying without reflecting on purpose or strategy
Treating the course as unrelated bits of knowledge
Memorising without understanding
Accepting ideas without questioning them

Monitoring studying
Keeping your studies well focused
Monitoring understanding and addressing any problems
Monitoring and developing generic skills
Monitoring and enhancing the quality of work produced

Organisation and effort in studying
Organising your studies
Managing time and effort effectively
Maintaining concentration

It is important that the approaches are not seen as labels for individual students as they are to some extent dependent on students' perceptions of their teaching-learning environments (Biggs, 1999; Entwistle, 1998b, 2000; Prosser & Trigwell, 1999; Ramsden, 1997). Further, the approaches are analytic categories which simplify the complexity of high-quality learning in higher education, but which cannot claim to describe it fully. The student learning literature, and the ideas emerging from the first phase of the ETL project, provide some perspectives on how this description might be further elaborated. In relation to students' engagement with their learning, their wider aims and goals, and the ways in which they use these aims in focusing their studies, are naturally an important concern (Beaty, Gibbs and Morgan, 1997; Morgan, 1993; Taylor, Gibbs and Morgan, 1980; Vermunt, 1996, 1998). As can be seen from the description of the approaches given in Table 1, the ways in which students monitor and regulate their learning are seen as important for this project. This is a theme which has been increasingly explored in the student learning literature (McKeachie, 1990; Pintrich and Garcia, 1991, 1993; Vermunt, 1996, 1998). The diversity of students' beliefs about learning and knowledge, and of their beliefs about specific learning tasks has also been an important concern in the literature (Campbell, Smith and Brooker, 1998; Hounsell, 1987, 1988, 1997; Norton, 1990; Marton, Dall'Alba and Beaty, 1993; Perry, 1970, 1988; Prosser and Webb, 1994; van Rossum and Schenck, 1984; Säljö, 1982). All of these aspects, including students' approaches, seem to be inter-related in complex and often reciprocal ways, and have each been shown to relate directly or indirectly to learning outcomes in higher education (Campbell, Smith and Brooker, 1998; Entwistle and Tait, 1990; Marton and Säljö, 1997; Pintrich et al., 1991, 1993; Prosser and Webb, 1994; Tait, Entwistle and McCune, 1998; Trigwell and Prosser, 1991; van Rossum and Schenck, 1984; Vermunt, 1996, 1998).

To some extent, high-quality learning can also be conceptualised in terms of the generic and subject-specific skills students use and develop. There are a number of different reviews now available in the literature which include a broad range of skills, many of which could be understood in either a generic or a subject-specific manner. For example, Bennett, Dunne and Carré (2000) cluster core and generic skills under four headings: management of self, which includes topics such as time management and reflection on learning; management of information, which includes using appropriate sources and technology; management of others, which includes negotiation and offering constructive criticism; and management of task, which includes setting priorities and using appropriate strategies. Some of these skills overlap the descriptions of approaches to learning and studying.

As we come to explore the nature of high-quality learning in the five subject areas included in this project, we will be considering student learning within specific disciplinary contexts. These contexts will each to some extent have their own norms, values, language and practices (Anderson, 1997; Ballard and Clanchy, 1988; Becher, 1994; Hounsell, 1988; Lave and Wenger, 1999; Ramsden, 1997). Students will consciously or unconsciously adapt to and reject different aspects of these cultures as they develop as learners. Considering all of the literature discussed in this section, and the findings emerging from the telephone interviews, the ETL team have developed the concept of 'ways of thinking and practising' in a subject area to encompass all of the different aspects of high-quality learning.

2.3 Ways of thinking and practising in the biosciences

There is now a number of studies in the research literature which point to aspects of high-quality learning which seem to be associated with ways of thinking and practising in the biological sciences (for example, Bond, Bullen and Elliot, 2000; Jervis, 1999; Manuela *et. al.*, 1998; Ryder and Leach, 1996; Séré *et. al*., 1998; Stefani *et. al.*, 1997). We have not provided at detailed review of that literature here, as the benchmarking document for the biosciences (QAA, 2002) gives a very comprehensive overview of what biosciences students might be expected to learn from their studies. In terms of the knowledge and understanding that students might be expected to acquire, the authors of the benchmark note that it is not possible to specify exactly what factual knowledge may be needed, given the width and diversity of the biosciences. Some suggestions are made, however, about the forms of subject knowledge and understanding which are likely to be important. These include, for example, a broad knowledge base, which provides the context for more specialised and in-depth understanding of particular areas. Figures 1 and 2 summarise what the report identifies as a 'good' level of attainment by honours graduates in terms both of generic standards and of standards for the specific sub-area of molecular biology.

Figure 1: Good generic standards in the biosciences
(QAA, 2002, p.8)

- to be able to access and evaluate bioscience information from a variety of sources and to communicate the principles both orally and in writing (eg essays, laboratory reports) in a way that is well-organised, topical and recognises the limits of current hypotheses;
- demonstrated ability in a range of appropriate practical techniques and skills relevant to research in biosciences. This will include the ability to place the work in context and to suggest lines of further investigation;
- 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 (eg 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;
- be able to construct reasoned arguments to support their position on the ethical and social impact of advances in the biosciences;
- be able to apply relevant advanced numerical skills (including statistical analysis where appropriate) to biological data;
- have well-developed strategies for updating, maintaining and enhancing their knowledge of the biosciences.

Looking at the student learning research literature, one relevant theme in relation to students' knowledge and understanding is work that focuses on biological sciences students' conceptions of specific topics - such as natural selection or photosynthesis – and the relationships between these conceptions and students' approaches to learning and studying (Brumby, 1984; Hazel and Prosser, 1991, 1994; Martin, Mintzes and Clavijo, 2000). These studies suggest that university students may have misconceptions of key topics and that these misconceptions may at times be quite resistant to change. A similar picture has also been emerging in other subject areas such as social sciences (Beaty, 1987) and mathematics (Crawford et. al., 1998). As would be expected, the deep approach tends to correlate positively – and the surface approach negatively - with more developed or accurate conceptions (Hazel and Prosser, 1991, 1994).

The interpretation of these correlations is complicated by the finding that students with a better background knowledge of a subject at the start of a course may take deeper approaches to learning within it than than students who had started with weaker background knowledge (Crawford et. al., 1998; Hazel and Prosser, 1991). This may perhaps occur because students who habitually take a deep approach have been more able to develop their conceptual understanding in their prior educational experiences. Crawford et. al. (1998) also found that students with better background knowledge perceived the same environment as more encouraging of a deep approach, than did students with weaker background knowledge. In their research with first year biology students, Hazel and Prosser (1991) demonstrated a small relationship between students' understanding of photosynthesis before and after a university course alongside a stronger relationship between the students' reported approaches during the course and their understanding at the end of the course. While this might be taken to suggest that the relationship between students' approaches and their conceptual understanding is not simply a function of their prior knowledge, a more complete understanding of these issues must await further research which more fully takes into account the complex web of influences on students' learning.

Figure 2: Good standards for molecular biology, incl. biochemistry
(QAA, 2002. p.9)

- understand and explain the chemistry that underlies biochemical reactions and the techniques used to investigae them;
- understand the principles that deternine the three-dimensional structure of biological macromolecules and be able to explain detailed examples of how structure enables function;
- have a critical understanding of the molecular basis of genetics, and be able to explain some detailed examples;
- have 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;
- 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;
- be able to devise and evaluate suitable experimental methods for the investigation of relevant areas of biochemistry and molecular biology;
- 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;
- understand the chemical and thermodynamic principes underlying biological catalysis and the role of enzymes and other proteins in determing the function and fate of cells and organisms.

The benchmarking document also identifies a range of subject-specific and generic skills, as well as ways of thinking, which are important for students in the biosciences. The skills addressed include numeracy and the ability to use information technology, interpersonal and communication skills, and the development of the capacity for lifelong independent learning

The use of methods of research appropriate to students' area of study is obviously important and this is related to critical understanding of the collection and use of information and data, and the relationship between findings and theoretical frameworks. The authors note that students should realise 'that much of what they are taught is contested and provisional, particularly in the light of continuing scientific advances.' (QAA 2002, p4). Students are also expected to be able to debate issues in a mature and critical manner, including an engagement with moral and ethical themes.

Research carried out recently as part of the Labwork in Science Education project seems relevant to understanding students' ideas about research, data and theoretical frameworks in the biosciences, although the reports from the study do merge findings from students of physics and chemistry with those from biology (see for example, Leach *et. al.,* 2000; Ryder and Leach, 1999, 2000; Séré *et. al.*, 1998). One key finding from this research was that students studying science in upper secondary school and in the first two years of university often had problematic ideas about the nature of scientific inquiry, and that their ideas about the nature of science were not consistent over different contexts. For example, the majority of the 731 students in the study used 'data focused reasoning' on some occasions, a view that suggests that measurement is a simple matter of copying from reality, that conclusions just state what happened, and that differences of opinion can be resolved simply by collecting sufficient data

(Leach *et. al.,* 2000). Most of the research on these issues has, however, been at school level so the position in higher education remains to be confirmed by further studies.

Overall, by drawing on the benchmark statement, and on the general and subject-specific research literature, it can be seen that ways of thinking and practising in the biosciences can potentially encompass many aspects. These would include forms of knowledge and understanding, generic and discipline specific skills, engagement, skill in learning, students' aims, values and beliefs, and more generally the ability to work effectively within a particular community. The next phase of the ETL project should be alert to all of these aspects. Later in this report, we will explore what the telephone interviewees had to say about these issues.

2.4 Teaching-learning environments, constructive alignment and learning

A principal aim of the ETL project is to explore the use of the concept of 'constructive alignment' as a way of investigating the impact of teaching-learning environments on students' learning. This concept originated in the work of John Biggs (1993, 1996, 1999) where he discussed how teaching-learning environments form complex interacting systems. This being the case, he suggested that attempts to improve the quality of the environment need to involve the system as a whole. Constructive alignment occurs to the extent that aspects of the system are set up so that they all support high-quality learning. As Biggs observes:

> In aligned teaching, there is maximum consistency throughout the system. The curriculum is stated in the form of clear objectives, which state the level of understanding required rather than simply a list of topics to be covered. Teaching methods are chosen that are likely to realise those objectives; you get students to do the things that the objectives nominate. Finally, the assessment tasks address the objectives, so that you can test to see if the students have learned what the objectives state they should be learning. All components in the system address the same agenda and support each other. The students are 'entrapped' in this web of consistency, optimising the likelihood that they will engage the appropriate learning activities . . .
>
> (Biggs, 1999, p. 26)

It is important to note here that we do not assume that there is any one right way to achieve a high degree of constructive alignment. Rather, there might be a number of possible ways of achieving this within any particular context, depending partly on the particular forms of high-quality learning that were sought by staff and students. Further, some aspects of the context will be outside the control of staff working on a particular module or course unit, so what will be of interest to us is what can be achieved within a particular set of constraints. Later in this report, we will give some indicative examples of constructive alignment from our analysis of the telephone interview data.

A key point to make in relation to the literature on the effects of teaching-learning environments on students' learning is that it is students' *perceptions* of these environments that are central. Different students may perceive the same setting in a variety of ways and prefer teaching of different kinds, leading to different effects on their learning. For example, students with different preferred approaches to studying, different conceptions of learning, and different levels of background knowledge, may perceive the same context in different ways (Crawford *et al.,* 1998; Entwistle and Tait, 1990; Säljö, 1982) . Given that students on any module are likely to differ in their aims, learning histories and skill in learning, the extent to which alignment can be achieved for diverse groups is an important concern. Related to this, students' sense of belonging to different communities – both within and beyond academic settings – and aspects of their identities will also be intertwined with their experiences of learning in higher education (Bamber and Tett, 2000; Tett, 2000).

Within the ETL project we are focusing on the teaching-learning environments in particular course units. Thus is it important to consider what aspects of those units might have an effect

Table 2: Generic features of high-quality teaching-learning environments identified within TQA/QAA reports

Curricula, teaching, learning and assessment	a. Overall programme design, incl. wide/coherent choice of options b. Structure of module/course, and of individual teaching sessions, made clear and linked to aims c. Content chosen to match students' prior knowledge, abilities, interests, and understanding d. Challenging content focusing on understanding, and academic and generic skills e. Good teaching, making appropriate use of supporting resources and teaching/learning technologies f. Careful control and monitoring of student progress, particularly in the early stages g. Encouraging progressively more independence in learning h. Stressing relevance of content to aims/vocational value, interplay between theory and practice i. Wide range of appropriate and varied assessment, backed up by timely, helpful feedback j. Small-group teaching / tutor-student closeness
Learning support	a. Staff-student relationships showing mutual respect and good rapport b. Identifying and supporting specific learning needs, incl. language, maths and study skills c. Seeking and acting on student feedback on courses and teaching d. Meeting 'personal tutors' regularly
Course organisation and administration	a. Effective quality assurance procedures b. Course handbooks detailing aims, teaching, learning resources, assignments and assessment c. Well-managed staff appraisal and active encouragement of staff development d. Well-designed, well-maintained and accessible accommodation, equipment and facilities

on the quality of students' learning. One useful framework stems from the project's analysis of teaching quality assessment reports (Cousin and Hounsell, 2002). This analysis provided a summary of features of high-quality learning environments, set out in Table 2. It consists of generic features of these environments as identified by TQA assessors, grouped under the broad headings of course organisation and administration; curriculum, teaching-learning and assessment; and student support. One limitation of this analysis, from our perspective, is that the quality assessment reports provided no direct evidence of the effects of different aspects of course environments on students' learning. Also, the reports say little about how the quality of the different aspects was judged; their focus is on evaluating the quality of provision.

There is, however, a research literature in this area which addresses these concerns. We will not attempt a full review of that literature here, but it is possible to identify a number of important themes. One key issue is the impact of assessment and feedback on students' learning

(Entwistle, 1987, 1998b; Entwistle and Ramsden, 1983; Hounsell, 1987, 1988, 1997; Laurillard, 1997; McCune, 2000; Scouller, 1998; Thomas and Bain, 1984; Wilson, Lizzio and Ramsden, 1997). For example, multiple choice questions, or assessments perceived as requiring reproduction, seem to push students towards a more surface approach. The literature also suggests the importance of students' experiences of the teaching on their courses (Anderson, 1997; Entwistle, 1998b; Ramsden, 1997; Trigwell and Prosser, 1991; Trigwell, Prosser and Waterhouse, 1999; Wilson, Lizzio and Ramsden, 1997). Some of the findings from these studies suggest that enthusiastic and empathic teaching with good explanations can have a noticeable positive effect on students' learning. Returning to the problem mentioned earlier - of students having misconceptions of key topics which may be resistant to change – there is some evidence in the literature that teaching which is more focused on students' conceptions and misconceptions may resolve some of these difficulties and encourage a deep approach (Trigwell, Prosser and Waterhouse, 1999). Appropriate workload and some freedom of choice for students in how and what they learn seem to encourage a deep approach but it should be borne in mind that students' ability to cope with this freedom is likely to depend on their current level of skill in organising their own learning (Vermunt, 1996). Looking at research into 'study skills' support, it seems possible to encourage aspects of high-quality learning when appropriate and timely training is given in relation to a student's work in a discipline (McCrindle and Christensen, 1995; Vermunt, 1995; Volet, McGill and Pears, 1995; Weinstein, Husman and Dierking, 2000).

Most of the literature just described focuses on the impact of teaching-learning environments on students' general approaches to learning and studying, but students' experiences of teaching-learning environments will also influence other aspects of their ways of thinking and practising. A full review of these issues is beyond the scope of this paper, but for the purposes of the ETL project it will be important to be aware that students may learn much about disciplinary cultures in a tacit manner, alongside more explicit teaching (Anderson, 1997; Ballard and Clanchy, 1988; Becher, 1994; Hounsell, 1988; Lave and Wenger, 1999; Sambell and McDowell, 1998; Snyder, 1971). For example, Anderson (1997) describes how students in social sciences tutorials have gradually to adapt to cultures in which tutors are being less directive than their teachers may have been at school and to a co-operative ethos which may also differ from their earlier experiences. The students also had to come to terms with the forms of academic discourse used in their disciplines. Returning briefly to generic skills, it seems that where students develop their approaches, or become enculturated into particular disciplines, they are in fact learning certain generic skills within a particular disciplinary context. More generally, it seems that students may respond better to efforts to enhance their generic skills when such training is integrated within their disciplinary studies (Bennett, Dunne and Carré, 2000).

2.5 Teaching-learning environments and student learning in the biosciences

This section gives a brief overview of two themes in research into teaching-learning environments which seem particularly relevant to the biosciences. The first is research into laboratory classes and science project work, as these activities are considered less often in the generic literature and are highly relevant to the biosciences. The second theme is problem-based learning, a topic which has received considerable attention in recent years, particularly in relation to medical education. It is also worth noting that there are a number of studies emerging in the literature which pick up themes from the broader higher education literature in biosciences contexts, for example, the work of Orsmond, Merry and Reiling on essay writing and on peer and self assessment (Merry, Orsmond and Reiling, 1998; Orsmond, Merry and Reiling, 1997, 2000).

Earlier in this report, we discussed some of the concerns that have been raised over the cost of labwork and its value for students' learning. Despite these concerns, the potential value of laboratory classes and project work for students' learning seems considerable in the light of our discussion of the different facets of high-quality learning. In an ideal world, laboratory and project work might help develop students' discipline-specific and generic skills, enhance their understanding of the nature of scientific inquiry and more generally help to induct them into many aspects of ways of thinking and practising in their discipline. As we have seen, however, resource constraints, and the pace at which the biosciences are developing may seriously limit what is possible in undergraduate laboratories. In looking at how the best possible outcomes might be achieved, perhaps the first point to make is that laboratory classes and project work cover a wide range of different types of teaching which can be expected to have different effects on students' ways of thinking and practising in the biosciences. The literature on how these different types of activity might impact on students learning is dated in places, and somewhat sparse, but issues relevant to the ETL project do emerge.

One important issue is the extent to which the students' work in the laboratory is directed and supported by staff (Bliss, 1990; Boud, Dunn and Hegarty-Hazel, 1986). This potentially has important implications for students' motivation and engagement. For example, over a decade ago Bliss (1990) reported data based on physics students stories about their experiences of undergraduate teaching which suggested that first year students tended to have more negative than positive experiences of laboratory classes in part because they found taking responsibility for doing the experiments very anxiety provoking. Students in the later years of their degrees did not have this problem and they were most motivated and engaged when they worked independently and took responsibility for open-ended experiments or project work. Later research into students' experiences of undergraduate projects, reported by Ryder and Leach (1996), suggested that even students in the later years of higher education could struggle with the amount of responsibility they were given for organising their own learning. The key point arising from these studies seems to be that students need to be given a level of control and responsibility over their learning appropriate to their developmental stage, so that they are able to gradually expand their skill in regulating their own learning.

The social environment of laboratory classes and the relationships between students and their supervisors also seem important for students' motivation and engagement. Ryder and Leach's study, for example, also highlighted the importance of a positive student-supervisor relationship for the quality of students' learning experiences. They argue that a positive relationship may be more easily developed where the supervisor has an awareness of the students' expectations, makes reasonable demands on the student, is aware of the students' level of motivation and tries to enhance that. Ryder and Leach also considered the wider environment within which these projects were carried out and suggest that an important concern is to try to get a fit between the students' preferred ways of working and the environment they end up in. They noted, for example, that some students prefer more social and lively settings, whilst others did better working on their own for much of the time (Ryder and Leach, 1996).

Tapper (1999) reports a study of the topics and manner of talk in second year undergraduate microbiology laboratories. Her work addresses some of the issues raised earlier, about enculturation of students into particular disciplinary communities, which may each have their own styles of interaction, although Tapper also points out that the students were not yet committed to joining this particular group. Nonetheless, she did find instances of talk which seemed to suggest that the students were 'bonding as a group of scientists as distinct from the outside community' (p461). For example, the humour used in the laboratory sometimes contrasted the knowledge and values of the scientific community against the less accurate understandings of non-scientists. Tapper also noted that an important feature of the lab talk was the ways in which it was used to 'save face' for students and to maintain a pleasant atmosphere, frequently with the use of humour. Tapper's work suggests that the generic skills of communication and team work may need to some extent to be understood within a particular disciplinary context.

Fraser, Giddings and McRobbie (1992) report a large scale study at tertiary level using the *Science Laboratory Environment Inventory (SLEI)* which addresses social and other issues in

Table 3: Scales from the SLEI
(Adapted from Fraser et al., 1992, p.435)

Scale name	Description
Student cohesiveness	Extent to which students know, help and are supportive of one another.
Open-endedness	Extent to which an open-ended, divergent approach to experimentation is encouraged.
Integration	Extent to which laboratory activities are integrated with non-laboratory and theory classes.
Rule clarity	Extent to which behaviour in the laboratory is guided by formal rules.
Material environment	Extent to which laboratory materials and equipment are adequate.

relation to laboratory environments. Extensive development work on this inventory suggested the scales set out in Table 3 to describe science laboratory environments. All of these scales (which relate to content-free rather than subject-specific processes) correlated positively with more favourable student attitudes to laboratory work, particularly the 'student cohesiveness' and 'integration' scales. 'Open-endedness' did, however, relate to negative attitudes for some groups of students. Fraser (1998) notes that the *SLEI* scales relate positively to both cognitive and affective learning outcomes in high school, but these relationships do not seem to have been explored at the tertiary level.

In our earlier discussion of ways of thinking and practising in the biosciences, we described research which suggested that students may have difficulties in understanding the nature of scientific inquiry. Boud, Dunn and Hegarty-Hazel (1986) provide a summary of work in this area (mostly at school level) which suggests that laboratory work can be effective in developing students' understanding of scientific inquiry. The authors suggest that this process will be easier when students have background knowledge of the area before the laboratory class, when teaching about the process of scientific inquiry is made explicit, and when laboratory exercises are designed for this purpose, rather than using a 'cookbook' approach. More recent work by Ryder and Leach (1999) - based on a small number of case studies with students from the biological and other sciences - suggests that one of the benefits of undergraduate project work is that it can develop students' ideas about the nature of scientific investigation.

Earlier in this paper, we mentioned that a number of authors have proposed that aspects of practical work might be replaced by some form of ICT. As yet, there does not seem to be an extensive literature on the impact of such packages on students' laboratory class learning in higher education, perhaps in part because the technology to provide high-quality packages within a reasonable budget has only become available relatively recently (Sewell, Stevens and Lewis, 1995). Nonetheless, there are indications that using ICT to replace practical work may have certain advantages in some contexts. For example, Sewell, Stevens and Lewis (1995) report that students using a multimedia CAL package to simulate pharmacology laboratory tasks enjoyed and were enthusiastic about the package and claimed that it helped their understanding, although this claim was not tested directly. Predavec (2001) went further down this line, comparing the multiple-choice grades of students randomly assigned to a traditional laboratory class or CAL. The students using CAL performed significantly better, even when time spent on the task was factored out, but it was not clear whether the MCQs tested understanding or focused more on factual recall. Both Sewell et al. and Predavec note that CAL packages can be useful for students who work more slowly, as they can return to the work later, an option that would not normally be available in traditional laboratory classes. These authors also point out that CAL packages can also reduce the need to use animals, which may be an advantage as staff and students become more aware of bioethical issues.

Moving on to consider problem-based learning, definitions of this method vary, but it typically involves small groups of students engaging in self-directed learning which takes some kind of 'real life' problem as its starting point. The literature in this area tends to focus most often on medicine, nursing and other professions, but there have also been studies looking at biological sciences courses more generally (Dahlgren and Öberg, 2001; Harland, 2002; Rangachari, 2000). Attempts to draw overall conclusions about the efficacy of PBL from the research literature are highly problematic for a number of reasons. The research has only been carried out over a short time period, a diverse range of techniques has been used under the heading of PBL, and the environments in which PBL has been embedded are complex and varied (Norman and Schmidt, 2000; Schwartz, Mennin and Webb, 2001). There is some evidence, however, that PBL can have positive effects on measures such as clinical performance, and students' approaches to studying and motivation (Schwartz, Mennin and Webb, 2001). It has been more difficult, however, to demonstrate positive effects of PBL on measures of knowledge, and the positive effects on clinical reasoning can be small (Norman and Schmidt, 2000). To date, there has been little research on the effects of PBL on other outcomes such as critical thinking, reflective practice and teamwork (Rideout and Carpio, 2001).

3. TELEPHONE INTERVIEWS OF TEACHING STAFF IN BIOLOGY

3.1 Introduction

This section of the report presents and discusses the findings emerging from telephone interviews with a small sample of biology teaching staff conducted within Phase I of the ETL project. The section briefly outlines the composition of the sample and the settings from which they were drawn, then goes on to introduce and present the analysis.

3.2 Sample and Settings

As part of the pilot phase of the ETL Project, ten interviews were carried out with staff in Biology departments in four universities in spring and summer 2001. Those interviewed had been identified by their respective heads of departments as having significant involvement in the teaching of a first-year or final-year course unit or module concerned with cell and molecular biology, or were well-placed (by dint of a role with e.g., responsibility for oversight of undergraduate teaching programmes in biology) to provide an overview of teaching within the department concerned. Each department had been given an 'excellent' rating (i.e. 22 or more points out of 24) in national teaching quality assessments, and together represented a cross-section of institutions – an 'ancient' university, a 'civic' university, a post-1960 university which had grown out of a College of Advanced Technology (CAT), and a post-1992 university which had formerly been a polytechnic. All four departments were well-established, and three had intakes of students who were predominantly well-qualified (and in two cases, exceptionally well-qualified). Caution is therefore needed in attempting to extrapolate implications for other departments where students' entrance qualifications may typically be lower or much more diverse.

In the analysis of teaching quality assessment (TQA) reports which had been undertaken in Phase 1 of the ETL project, three orientations to teaching had been identified which mirrored the wider concerns of particular departments but also influenced their curricula, learning-teaching activities and assessment strategies. Departments with an *access* orientation actively encouraged and supported students from disadvantaged backgrounds and/or without conventional entrance qualifications); departments with a *professional* orientation prized links with employers and the professions; and in departments with an orientation towards *research* , teaching aspired to be 'research-minded' or 'research-led', especially in the later years of undergraduate study.

These differing teaching orientations were also evident in the four departments from which the telephone interviewees were drawn. Thus one of the four (in the former CAT) had a strong professional orientation and its students spent their third year on industrial placements:

> *extract 2*
>
> The department tends to attract students who already think of themselves as working in the area, particularly because it offers sandwich courses. The sandwich programmes ensure that what is taught will be relevant to employment in biology. This is partly because staff visit the students and see if there are any gaps in what the students have. The students have an image of themselves working before they apply. That has positive effects both on the intake and on the outcomes …Also in the final year you may have a student who is an expert in any area in the audience for your teaching because they have spent a year on placement.

Another (in the former polytechnic) had a significant access orientation:

> *extract 3*
>
> There is a large number of students coming in with A levels through the standard route, but there are also a lot of entrants with non-standard qualifications. Some come in through the foundation scheme which is mainly for mature students and students who have not met the A level requirements. The foundation scheme is run through a local FE college. Some of these students have turned out to be among the best on the course, they are among the top firsts every year . . . After the foundation year the non-traditional students fit in well with the rest of the cohort. These students seem to improve the atmosphere in the group because the ones that do get through the foundation course are very motivated and they set a good example to the other students, who are perhaps not as well motivated.

However, while the other two departments (from an 'ancient' and a 'civic' university) could be viewed as having a predominantly research-focused orientation to teaching , all four departments were committed to the pursuit of research in the biosciences, and (as will be apparent in many of the interview extracts in the analysis which follows) this was reflected in their curricula and teaching in various ways. Indeed, as the earlier TQA analysis suggested, these teaching orientations should not be considered as mutually exclusive, but appear instead to reflect varying degrees of emphasis along continua.

3.3 Design and Conduct of the Interviews

An interview schedule was drawn up for use in the telephone interviews across all five subject areas (see Appendix 1). The schedule was emailed to interviewees in advance, to give them the opportunity if they so wished to collect their thoughts prior to the interview. In preparation for the interviews, members of the project team also searched relevant departmental web-sites to brief themselves on curricula and teaching-learning and assessment arrangements.

All of the interviews were tape-recorded, with the permission of the interviewees. The interviews were subsequently transcribed in the form of extensive notes of responses to questions in the interview schedule. Selected comments were transcribed verbatim where deemed appropriate. Those interviewees who so requested were sent a copy of the protocol for their interview, with an opportunity to propose amendments if they so wished.

3.4 Analysis of Interviews

The analysis of the interviews gave priority to two themes which, as we have already seen, are central concerns of the ETL project. The first of these focuses on what the interviewees took to be high-quality learning in the subject, which is presented in the analysis as facets of ways of thinking and practising in biology. The second focuses on how high-quality learning was facilitated or 'operationalised', which is analysed from the perspective of constructive alignment.

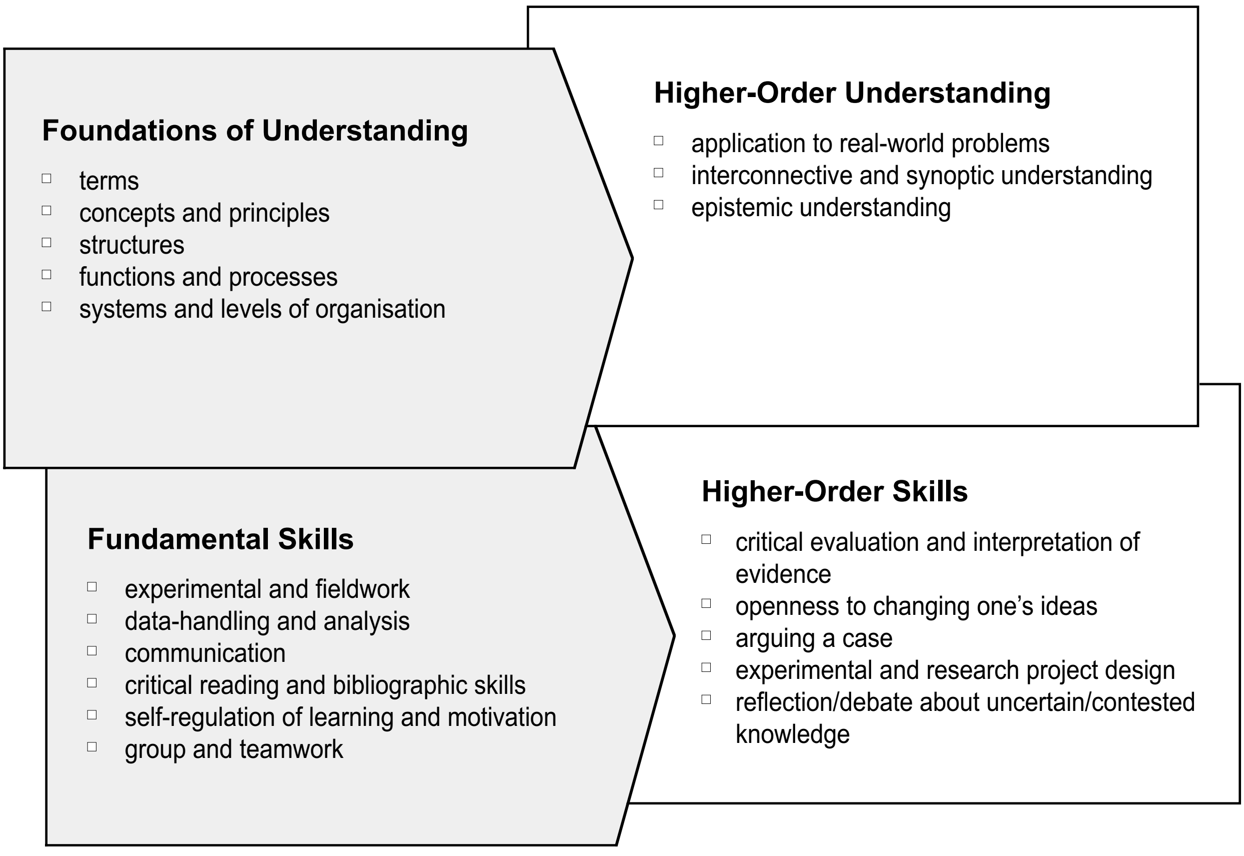
This initial analysis was necessarily provisional and tentative, and should not be seen as in any sense definitive, particularly given the focus on departments with high teaching quality ratings, the modest overall sample size, and the small number of respondents in each setting, all of whom were teaching staff. The intention, rather, was to explore and identify potentially fruitful questions and lines of enquiry which could be more systematically pursued in the main phase of the project.

Each component of the analysis is illustrated below with extracts drawn from the ten interviews (indented). Verbatim extracts appear in single inverted commas; all other extracts are in note form. Each extract is numbered in order of appearance, to aid cross-referencing. Extracts have also been individually tagged with a letter indicating the institution (a = post-1992; b = ex-CAT; c =civic; d = ancient), the number of the interview (1-10), and the section of the transcript from which it is taken.

3.5 Ways of Thinking and Practising in Biology

In analysing the phone interviews, two interrelated aspects of ways of thinking and practising in biology were identified: forms or kinds of understanding which students needed to acquire, and a range of skills, techniques or competences through which students enlarged, applied and

Figure 3: Aspects of Ways of Thinking and Practising in Biology



communicated their grasp of the subject. Each of these two aspects could be differentiated in terms of two levels, one comprising the fundamentals or building blocks of subject mastery, the other higher-order capacities which seemed to grow out of these but extended beyond them. Figure 3 summarises these interrelated aspects and levels, many of which broadly mirror the range of understanding and skills identified in the QAA benchmarking report summarised in section 2.3 above.

While these ways of thinking and practising the subject are considered here as defining features of high-quality learning, it should be noted that interviewees also pointed to other qualities or attributes which they saw as contributing to academic success. These included effort, motivation (closely linked to confidence), independence in learning and studying (which would appear to overlap with the higher-order skill of self-regulation in learning), and gaps in prior knowledge (e.g. of chemistry or maths).

3.6 Foundations of understanding in biology

What might be called the foundation stones or building blocks of understanding in biology included a sound grasp of: key terms; core concepts and principles (incl. ones drawn from chemistry and physics); biological structures, functions and processes; and biological systems and levels of organisation. These are illustrated in the following two comments by interviewees:

> *extract 4*
>
> One of the key concepts for the whole of the first year is to get students to appreciate the different levels of organisation of biological systems represented by the three first year courses – cells and genes, organisms, populations. Students come in with an 'animals, plants, microbes' view of the world, and in the first year we want to get the students to move away from that to think about these different levels. (d6 B1)

> *extract 5*
>
> What is fundamental is not being confused about replication, transcription, translation and control. The students need to know that all of these processes are polymerisation (except for control) and that there are three stages in polymerisation (initiation, elongation and termination) they need to know the molecular detail for each of these processes. (a9 B1)

3.7 Higher-order understanding in biology

In the interviews, staff also pinpointed certain forms of understanding which seemed to go beyond these fundamentals, whether through applying them, grasping interconnections between them, or apprehending their derivation. Not surprisingly, these more advanced forms of understanding were generally associated with the later years of undergraduate study. The forms of understanding identified were:

- the **application of understanding** to real-world problems

> *extract 6*
>
> This course assumes that students know that basic enzymology and focuses on its application to biotechnology and medicine. (b2 B1)

- **interconnective and synoptic understanding**, e.g. of patterns and relationships, of levels and interconnections between them, taking a broad, holistic view of the subject as a whole or major areas within it

> *extract 7*
>
> The students are not at all good at detail and remembering facts, pinning facts together. (a9 D3)

extract 8

'... So it's very, very detailed cellular molecular biology trying to show them how complex solutions are produced ... if you have a simple [requirement], you're short of nitrogen in the environment, and to make use of atmospheric nitrogen you need to acquire some very specific enzymes to enable you to make use of that nitrogen, but there are other problems associated with it. You need also to produce an anaerobic environment which is difficult for an organism that is generating oxygen. So, you know, they have this simple requirement, we need to fix nitrogen, and to be able to do it there's a fairly complicated solution you need to develop. ' (c1 B2)

extract 9

One of the key things staff are trying to do is to get students to integrate what they have learned in separate modules earlier in the course about molecular techniques in biology, biochemistry, cell biology and whole organism biology. The module is one of the first points where they students are trying to get all of those things together to get a sense of the whole biology of a process rather than one aspect of it. (a7 C1)

extract 10

... Students who work in molecular biology tend to be focused very heavily at the biochemical/molecular level and it is very important that they understand the principles of evolution in order to see where the detail that they are studying fits within the general scheme of things. (a4 B3)

- **epistemic understanding**, of how knowledge is generated and derived through experimentation

extract 11

The emphasis is on the experimental basis of understandings in biology. In the previous year, the students have been taught simple parts of the biology of development, but in this module they concentrate much more on understanding how the experiments that people have done underlie that knowledge. (a7 C2)

extract 12

Students need to understand how things are known in this area, rather than simply being given lots of facts. So they need to know about experimental techniques and the interpretation of findings. Ultimately you want them to leave the programme being able to think about how to design their own experiments. You begin this by showing them how other people have designed experiments and tested things. (b3 C1)

extract 13

We are very keen in the ... course to get the students to think in terms of experimental evidence rather than simply presenting facts. What we are presenting is the process that has led to those facts being considered to be true. ... Within cell biology you can easily and rapidly go through 40 years of history of the development of an idea and see how the experiments are put together... (d6 C1)

3.8 Fundamental skills in biology

As with forms of understanding, so also the skills referred to by interviewees could be seen in terms of two levels, the first of which comprised the fundamentals or 'building-block' skills of biology as an undergraduate subject. Although some of the skills highlighted are often seen as generic in the higher education literature, they were perceived by respondents predominantly in a subject-focused rather than content-neutral way. They included:

- experimental, practical and fieldwork skills

- data-handling and analysis (incl. statistics)
- communication skills (written, oral and mixed-media/presentation)
- critical reading and bibliographic skills (incl. primary literature and use of databases)
- student self-regulation of learning (e.g. time-management, responsiveness to feedback)
- group and teamwork skills

Extracts 14 and 15 below illustrate respectively references to presentation and critical reading and bibliographic skills, while extracts 16-18 refer to skills of self-regulation.

> *extract 14*
>
> Most of the students give their seminars on PowerPoint: they are very proficient at this. They can incorporate pictures and work with packages that allow them to manipulate molecules on screen. Students also need to have other presentation skills such as making eye contact with the audience, and responding flexibly to the audience. (b2 C1)

> *extract 15*
>
> In first and second year the students would be given some sort of a reading list to do the reading for their tutorial essays. By third year the staff are very keen that the students should go and explore the literature for themselves and by that time they should have the skills to do this. They should be able to pick up original literature and track ideas through the literature. (d5 C3)

> *extract 16*
>
> 'What influences their chances of doing well? I think the amount of work they do really. So the more conscientious students do extremely well ... What they have to be is proactive, to do really well. We try to encourage them always to come and see the members of staff who are doing the teaching if they are having difficulties. If they fail to do that, then that will obviously influence the outcome ... ' (c1 E1)

> *extract 17*
>
> [What] affects students' success more than anything else is their ability to work independently, to be an independent learner. This is the issue with most of the students who fail ... The most important thing is the ability of students to settle down to a pattern of working in their own time when they make the transition from a school or sixth form college to university where they have more freedom and where no one is chasing them up to do the work... (a4 E1)

> *extract 18*
>
> One problem is that we are taking on students who have been very successful and the vast majority have to come to terms with no longer being very successful relative to their peer group. That can really affect their motivation because for six or seven years they have been motivated by coming top of the class... (d6 E3)

It should also be pointed out that, although it is convenient to refer to these competences as 'skills', their effective deployment was sometimes seen by interviewees as contingent upon an understanding of underlying principles (e.g. of probability, in statistics), or of their application in context, as in the following comment:

> *extract 19*
>
> Statistics has changed over the years; there is less need now to calculate by hand as this can be done with computers. What is important is to get students to understand what techniques to use in what situation and how to interpret the output. So the emphasis has changed completely over the last ten years. Staff now expect students to have a deeper understanding, rather than knowing how to turn the handle to do the calculations ...(a4 D6)

3.9 Higher-order skills in biology

A number of higher-order capacities seemed to rest on and grow out of the foundation or 'baseline' skills. They comprised:

- **critical evaluation and interpretation of evidence** (including the drawing of sound conclusions)

  extract 20

  The module says to students that you have all the facts you need about enzymes, and what is wanted is that the students explore the literature and give a critical (not a reproductive) account, they have to evaluate the literature. This is why it is a final year course as it builds on their experience of doing research on placement. This ability to be critical is an extremely important part of their training, given that around 50-60% of the students go on to do PhDs and most go on to do some form of scientific employment. (b2 C2)

  extract 21

  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. 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. (d6 D1)

- **openness to changing one's ideas**, as new evidence accumulates

  extract 22

  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. This is important in all aspects of life, not just in molecular biology... (c1 C1)

- **arguing a case**

  extract 23

  'An ideal [tutorial] perhaps in the third year could be much more exploratory, so you could set a challenging topic which you know there is a lot of debate in the literature and then the individual will go to the library and ... having spent a week doing that reading ... they will have researched areas often more than perhaps the individual tutor will be aware of ... should have put it all down as an argued case bringing out the various controversies and then in the tutorial one would have a discussion ... really it's meant to be a discussion about the ideas that they've come across ...' (d5 C2)

- **experimental and research project design**

  extract 24

  Projects have many benefits for students: they help with teamwork, allow them to go in detail into a topic, give a flavour of what it's like to work as a biologist, allow practice in designing experiments (which doesn't happen in earlier years) so students have more control over the research process. It helps teach them to analyse data and present a concise report. (c1 F2)

  extract 25

  The students also do project work in the final year... The idea is to get students to work more independently and to start to do their own experimental design... (a7 F4)

  extract 26

  [Students] have to plan the project, and that planning is included in the project write up, they have to provide charts of what they intended to do and of what they ended up doing. ... The project allows the students to be involved in 'real research' – they are not pre-prepared packages that will fit into a six-week slot. (d5 F2)

- **reflection and debate** about areas within the discipline where knowledge is uncertain or where there are contrasting interpretations

extract 27

'There are various models for how you might get protein processing through the Golgi apparatus and there are two major hypotheses at the moment that are slugging it out in the literature and so we would introduce them to ... presenting both sides of the case so they are now beginning to get the difference between an accepted view and where, how you inform the particular debate. Because it's all based on experimental work ... ' (d5 C2)

3.10 Further instances of ways of thinking and practising

Over and above the examples already presented, many further references by interviewees to characteristically biological modes of thought and action appear in the sections below, where the analytical focus shifts to questions of alignment with curricula, teaching and assessment strategies. (See for example, extracts 31-33, 35-43, 52-53, and 55-61).

3.11 Constructive Alignment and the Facilitation of High-Quality Learning

This section of the analysis considers how high-quality learning was perceived to be promoted or operationalised by interviewees. Interviewees' observations and reflections are viewed in the analysis from the perspective of constructive alignment. As articulated by Biggs, constructive alignment is concerned primarily with the pedagogical 'goodness-of-fit' between high-level learning objectives (represented in the present analysis by aspects of ways of thinking and practising in the subject) and teaching-learning strategies or activities (TLAs) and assessment. The present analysis extends Biggs' model to encompass three other aspects of alignment which it also seems important to take account of. All three can reasonably be taken to be salient dimensions of teaching-learning environments when such environments are considered, as in Biggs' model, as systems made up of interlocking components "which address the same agenda and support each other" (Biggs, 1999, p. 26).

The three additional aspects are:

- alignment to the students taking the course units concerned
- alignment of learning support, i.e. the supplementary help and support offered to students on learning and studying
- alignment of course organisation and management

3.12 Alignment to Students

In the interviews, indications of alignment to the students taking the courses discussed were especially apparent in references to curriculum design and development. One interesting cluster of comments, evident in at least three of the four course settings, was concerned with the *responsiveness of curricula to diverse student needs and capabilities.*

extract 28

I am not sure that there are specific topics that the students find difficult. Different parts may be difficult for different students. It is a foundation course so you have to take into account that the students are at different levels. The students will lose interest if they get lost in the vocabulary of the subject. Maintaining student motivation is one of the most important factors. The staff make sure that students coming in without A-level biology aren't faced with lots of unfamiliar terms, so they start at the lowest level. All of the lecturers work from one textbook to give some consistency across the course. Extra reading and electronic material is aimed at students who don't have biology backgrounds. During the lectures the level ranges from one end of the spectrum to the other, so that the students with a stronger background are also satisfied. (b3 D2)

extract 29

At level one the staff try to address problems in the background knowledge that students have in areas such as numeracy and chemistry. There is a mismatch between the mathematical skills taught at A level and what is needed for university biology. Topics like the use of logarithms and exponential functions do not feature highly in the A level syllabus, but many processes in biology are exponential or asymptotic in some way. Students do find the statistical elements in molecular and cell biology hard to grasp, although I do not think these are particularly difficult. (a4 D1)

extract 30

There is considerable diversity among the students in their ability to cope with the course despite the homogenous and well-qualified intake. Some students adapt to the content or different ways of thinking very much more easily than others. If a student were having difficulties it would be dealt with in the tutorial system where students are often working with staff 2 :1 or 3:1. This works very effectively. (d6 D4)

Another group of comments appeared to reflect *a developmental perspective on curriculum design*. There were indications of an alertness to 'where students are' in their evolving grasp of the subject, combined with a sense of how materials or tasks may be optimally sequenced or 'staged' (and a readiness in one instance to change curricula) to optimise learning. Instances of this developmental perspective on the curriculum can readily be found in all four institutional settings, as illustrated in the following extracts from the interviews.

extract 31

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. This is important in all aspects of life, not just in molecular biology. This is encouraged throughout the course, beginning in first year. At third year there are discussion groups and seminars where students can practice these skills for themselves. Also staff critically evaluate experiments in lectures, helping students interpret them and showing them the weak points. Students are also encouraged to read critical reviews. The students are not slow in coming forwards so lectures can be very interactive at third year, and this is encouraged from first year, although first years find it difficult. This is partly the type of students that we get: it really only takes one student in the class to start this off and a bandwagon develops. (c1 C1)

extract 32

A lot of these qualities have been instilled into them particularly in their placements. They will have practised presentations then. In a research environment (placements and final year projects) they get a chance to design experiments and discuss them with supervisors. It helps them if they try to interpret their data themselves before asking their supervisor for help. So they are gradually being taught to ask the right questions, which is crucial. (b2 E5)

extract 33

'In the first year most of the material would be non-controversial, it would be relatively straightforward textbook information. In the second year we are beginning to open up the debate. So one example would be there are various models for how you might get protein processing through the Golgi apparatus and there are two major hypotheses at the moment that are slugging it out in the literature and so we would introduce them to ... presenting both sides of the case so they are now beginning to get the difference between an accepted view and where, how you inform the particular debate. Because it's all based on experimental work and that's a way of leading them into the original literature as well.

'And then in the third year ... the idea that they will be dealing with loose ends is something else that we are very keen on, that they move away from the idea that we understand everything about a subject to making sure that they have got the core knowledge and then dealing with all of the areas which are not understood ... so sort of controversial in that respect ... ' (d5 C2)

extract 34

Students find some of the concepts in genetics difficult. In response to these difficulties that topic has been moved from level 1 to level 2 in order to allow the students to mature in their thinking before they tackle it. There used to be a very high fail rate at level 1 but moving the course to level 2 made a huge difference. The staff members who are teaching in this area in second year are flexible and enthusiastic and are constantly looking for new ways of doing things. One of the lecturers has taken a lot of time to put his lecture material onto CD ROM and to make links so that students can work on this material in their own time. The materials include some problems that the students can work through. The students seem to respond well to this, the numbers of students going on to take the microbial genetics option has doubled over the last couple of years. The respondent sees this as a good indication that more of the students are now comfortable with genetics . . . One of the good things about unitisation of courses is that it lets you alter them and move them about between years without causing problems for the programme as a whole. (a4 D2-3)

As extract 60 below suggests, however, staff could differ in their views as to how student development might best proceed.

3.13 Alignment of Teaching-Learning Strategies

The teaching-learning strategies reported and discussed by the interviewees generally took the form of lectures, group-based activities of various conventional and less conventional kinds, and practical work, complemented by independent study. Neither CAL nor problem-based learning was referred to, but this may simply reflect the particular teaching responsibilities and interests of the interviewees rather than departmental practices in their entirety.

From the standpoint of alignment, one notable feature of interviewees' reflections and observations was a well-differentiated and interconnected view of the roles and functions of particular teaching-learning activities in promoting ways of thinking and practising in the subject. Rather than simply being considered in isolation, teaching-learning activities were most appropriately seen in the context of a blend of teaching-learning activities and assigned work, as in the two examples below.

extract 35

The lectures concentrate on getting the factual information across, but also discuss the experimental basis of the topics. The students are then set readings which describe the key experiments in detail. Each student has to then summarise some of those papers, so they have to understand how the experiments and the conclusions are related and what experimental approaches can be taken to answer a particular problem. They also have a workshop on choosing the right experimental approaches to particular developmental questions which involves small group work with lots of staff support. The students seem to find it relatively straightforward to understand the experimental basis of the topics. (a7 D1)

extract 36

Quite a lot of tutorial work will be focused on quite a narrow topic, exploring it in a lot of depth, and that always involves some discussion of experimental evidence ... Teaching students to think like a scientist is almost done in an apprenticeship model but you can't take that metaphor too far. It is almost like the tutorials and lectures involve demonstrating how to carry out that way of thinking. Even though it is difficult to specify what that way of thinking is, it is hoped that by observing it and then taking part in it students will learn that skill. (d6 D2-3)

Group-based activities of a variety of kinds appeared to be especially important in promoting and supporting high-quality learning. In some departments, these took the form of tutorials in their conventional form:

extract 37

At level 1 and level 2 there is now a formal tutorial system involving small groups of students (6-8) working with an individual tutor throughout the year. If the students and the tutor get on then this relationship continues for the whole degree. In semester one the tutorial system concentrate on writing essays and putting together reports. The students don't seem to have had as much practice at writing essays as they did many years ago. The level 1 tutorials also work on basic numeracy. This is done using a book which one of our former graduates helped the department to publish. He came back and helped with a lot of the marking to make sure that the book was doing its job. The book includes a lot of self-assessment examples. It has been necessary to start at a very low level, for example, doing fractions and percentages. In semester two the focus on essay writing is continued and statistics is introduced. At level 2, mathematics is taken further including weekly assessments to make sure students are keeping up. The staff member teaching this has put a lot of time into providing self-assessment materials and manages to carry most of the students with him. He also tries to show students the biological relevance of the mathematics. They are also using the small group tutorials at level two to allow students to tackle biological problems such as the interpretation of data sets, data manipulation. (a4 D5)

extract 38

'In the tutorial you have an opportunity not just to discuss the subject material but also how the argument is put together ... Within the tutorial there is really an enormous amount of opportunity to spend time for each individual depending on exactly what their need is ... [In their tutorial essays] we are giving them areas ... where there isn't if you like a single story ... we would like them to tackle that information. So what we are asking them to do ... is to start developing their own view of the subject ... they must understand the information and bring it together, but we are asking them to try and express opinions as well, and for that they need to be able to argue the merits of both sides or perhaps even highlight some of the areas that they think should be addressed and if possible bring maybe their own solution ... because the tutorials are never marked in the sense of contributing to finals ... We are very keen on encouraging people to put their own ideas in, even if those ideas are wrong ... it allows them to develop their own view of the subject ...' (d5 D1)

But there were also examples of other kinds of group activities which were not in the conventional mould and were designed so as to pursue ends associated with specific aspects of ways of thinking and practising biology that could not readily be promoted through traditional tutorials. One example given was of classes which focused on a variety of skills – including numeracy, group presentation, and debating skills – which are embedded within, and seen as highly relevant to, the topic of cell development:

extract 39

In the second year, instead of having tutorials, there is a series of classes of around eight students which cover different skills. In one class they do problem solving which trains the students' numerical skills within the field of cells and development; in another they do a group presentation on a contested area; a third class focuses on literature around contested topics and different students get different pairs of papers which they present to the group which should then stimulate discussion because the students' shouldn't agree. (d5 C4)

Another example is of classes designed to help students gain a firm grasp of the skills needed to think and practise the subject well:

extract 40

The students get study support skills classes which include basic mathematics and statistics, reading the scientific literature properly, doing projects. The students are taught about how to design experiments and controls, how to write references properly, how to search the literature. (a9 D4)

A third example is of workshops geared to promoting *interconnective and synoptic understanding:*

extract 41

There are workshops which concentrate on integrating different aspects of biology. The students are split into small groups and first they work together on, for example, an aspect of gene expression during development. Then postdocs and lectures come in and work with the groups and at the end of the session each group does a short presentation. The aspects which the students work on are chosen to help them integrate between different areas of biology such as whole organism and molecular. This was started three or four years ago as the respondent noticed that integration was a problem for the students. It was noticeable from the outset that this initiative was helpful, even beyond that particular module. A lot of the students who had been on this module got very high marks across their courses. The aims of these workshops are made explicit for the students. (a7 D3)

Two further examples use group-based activities to enable students to hone their skills in surveying and critically evaluating the research literature. The first of the two builds on students' placement experiences, allying evaluative skills to practice in giving presentations; the second is in workshop mode.

extract 42

Most of the students give their seminars on PowerPoint, they are very proficient at this. They can incorporate pictures and work with packages that allow them to manipulate molecules on screen. Students also need to have other presentation skills such as making eye contact with the audience, and responding flexibly to the audience . . . The module says to students that you have all the facts you need about enzymes and what is wanted is that [you] explore the literature and give a critical (not a reproductive) account, they have to evaluate the literature. This is why it is a final year course as it builds on their experience of doing research on placement. This ability to be critical is an extremely important part of their training given that around 50-60% of the students go on to do PhDs and most go on to do some form of scientific employment . . . Students have to search and read the literature, so they have to get used to using search engines . . . Students have to be able to criticise other students' presentations . . . Students can sometimes find it difficult to be critical of research studies. It is hard to be critical when you've not been involved in the design of a study or in discussing it with colleagues. Student sometimes get feedback from staff on critical thinking after their presentations:

for example, the student may not spot a conflict between two conclusions drawn from different studies. These issues may also come out in the class discussion; assessing students' participation helps this process. (b2 D1)

extract 43

How the issues around interpreting experimental evidence are taught to students is very variable depending on the courses they take later on. 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. 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. This is taught in a workshop format. (d6 D1)

3.14 Alignment of Learning Support

All four of the departments from which the interviewees were drawn had in place mechanisms to provide additional support to students experiencing difficulties with their learning and studying. Alignment in this respect was not with particularised aspects of ways of thinking and practising biology, but with the quality of student learning more generally. If constructive alignment is to be considered from the standpoint of a system, then, the learning support component has an auxiliary or 'back-up' function in relation to the other components.

Learning support in the four departments took varying forms. In some instances (as some of the examples above will already have suggested), tutorials and other group-based activities provided scope, to varying extents, for students' individual needs to be addressed.

extract 44

The students' motivation is important. It is difficult to monitor that many students but it's important as there are so many other distractions in the first year. Trying to make sure they are all keeping up and they are all happy. The lecturers do encourage interaction, although the students are reluctant to ask questions in such a large class, but they are encouraged to approach the lecturers and there is a good tutorial programme which provides a safety net. The tutorial programme goes across all of the modules; students stick with one tutor who can help students to approach lecturers. (b3 E1)

extract 45

The students do statistics in the first year (and in later years) and there is huge variability in the students in their ability to do this work. Again the tutorial system is used to support students who are struggling. Biologists need statistics but many biology students find the mathematical side difficult. (d6 D5)

In other instances, the support provided extended beyond mainstream teaching-learning activities to remedial or one-to-one tutorials, additional classes, and an early-warning system based on formal periodic assessments.

extract 46

The respondent does spend a lot of time with students helping them to understand what they need to do to get by on the course. Students with difficulties are given remedial tutorials. (a9 D3)

extract 47

People who are struggling get one-to-one tutorials. The students may ask for these, or the staff may suggest that a particular student comes along. This often seems to be helpful, the failure rate for students who accept help is very low. Where there are problems is when students who are struggling won't come for help, these tend to be the students who fail. (a7 E5)

extract 48

They have a personal tutor set up to help students in difficulties. They have additional mathematics and chemistry classes for students having problems in that area. The general chemistry teaching they do is designed for biologists which can make it more approachable . . . The dean of students runs a university wide support system to support student learning and teaching. That dean is responsible for assisting students who have a wide range of difficulties. (b8 D1-3)

extract 49

The aim is to pick up problem areas as soon as possible, via a sort of early-warning system. The approach, which is to use assessment, (and is Faculty policy), 'may be a little old-fashioned, but seems to work well'. So there are formal assessments twice in the first year: at the end of November, and in March. If students are having problems, they have to go and talk to their tutors about why they have not performed well – this time round, students were asked to write to their tutors explaining why they've failed. 'And they are quite good at managing their own affairs . . . So we feel that rather than pulling them up and dressing them down, it's best to use a self-examination approach — and from there, we can work through the tutorial groups to try and improve their learning . . . And by the end of their first year, they do feel more confident about their ability to perform at the right level. (c10 D1)

3.15 Alignment of Assessment

The use of a wide range of assessment methods, with widely varying assessment weightings, was reported by the interviewees. The methods used included end-of-year exams, practical reports, coursework essays, oral and seminar presentations, poster presentations, and (in all four settings) final-year projects of a quite substantial kind. There were also two instances of student involvement in assessment: in peer feedback on lab reports (where concerns were raised about the rigour of peers' assessments); and peer involvement in assessing oral presentations (where the experience was much more positive).

However, referring to methods of assessment in the present analysis simply by their conventional labels may be misleading, since it has been common in the educational literature to associate particular methods with specific, well-established purposes or functions. (Indeed, Biggs himself risks taking such associations for granted). What seemed rather more fruitful in the present study (while at the same time bringing to the fore questions of alignment) was how a particular method was actually focused and deployed in a given course setting to facilitate the achievement of specific ways of thinking and practising in the subject. Thus an explicit and distinctive rationale would be given by interviewees for the assessment approach adopted and how that approach was 'angled' or 'focused' towards high-quality learning, as in the following examples.

extract 50

The two-hour exam paper for the module is its only assessment. It's in two parts, with very different questions in each. The first section focuses on analytic skills and their ability to synthesise information, it can be data handling or taking information and presenting it in a novel way. They quite often get presented with a scenario and are asked how they would conduct experiments to explore a hypothesis. Whereas the second part is just testing their 'factual understanding,' a more traditional essay question. (c1 F1)

extract 51

Essay topics are selected to be ones where they could not go to the literature and just look up keywords or particular papers. They require some lateral thinking based on their notes and prior knowledge, not just writing down facts. These essays do tend to divide the class into stronger and weaker students. Although this may seem subjective, the cross marking is very consistent. An example of this sort of essay question is, 'Why are enzymes proteins?' So a student might start by thinking about what is needed for a good enzyme catalyst, then show how proteins can do that and how other macromolecules can't. Another perspective is to say that what evolves depends on what raw materials evolution has to work on. Doesn't matter what answer is given as long as there is a reasoned argument . . . Given the focus of the course on biotechnology and medicine it's important that students come up with good examples, things that are meaningful for them. For example, they may understand how their biological washing powder works, or they may learn about a genetic disorder that they have. Having meaningful topics like this helps student learning. (b2 F2-3)

extract 52

The practicals are assessed on the basis of actual physical practical performance, i.e. how good the students' data is rather than a write up. It's choosing a key technique, letting the students do it and photograph their results and looking over the results. This is a small part of the assessment but it's important that students have experience of these skills and the students enjoy it. A lot of the students go onto PhDs so these skills are very important. (a7 F2)

extract 53

The students have to do two paper précis. One of these is more essay based, about a paper and the subject that it is on. The other is an actual précis of a paper, trying to summarise out the essence of a research paper and criticise that. This is done because it's important that students can read and understand research papers. (a7 F3)

extract 54

The first exam paper in the final year has a mix of short-answer questions which are designed to probe the breadth of students' knowledge. The second part of the first paper deals with problems, including numerical handling. The second paper is essay questions. These are designed to give students an opportunity to drawn in threads from different areas. The idea is that the essay writing skills from the tutorials, such as designing arguments, feed into this paper. (d5 F3)

As already noted, projects were a feature of final-year work in all four departments. Projects were linked to staff research and the research facilities available in the department, and clearly prized as a challenging means by which students could consolidate, deepen and demonstrate their grasp of ways of thinking and practising in biology. Indeed, rather than being geared to the pursuit of a single learning outcome, projects characteristically sought to facilitate a cluster or 'bundle' (Allen, 1996) of high-level learning outcomes:

extract 55

Students also do research projects (not specific to this module). These are done in pairs and link to staff research interests. Minimum time commitment students are supposed to devote to this is twelve weeks of afternoons but some put in more time. Projects have many benefits for students. They help with teamwork, allow them to go in detail into a topic, give a flavour of what it's like to work as a biologist, allow practice in designing experiments (which doesn't happen in earlier years) so students have more control over the research process. It helps teach them to analyse data and present a concise report. Also helps with oral presentation skills. They give an oral presentation part way through the project which is an important source of feedback. (c1 F2)

extract 56

Most students do a research project in the research labs in the final year. The students choose the areas they want to work in. The students are designing their CVs as they go along, so may choose to do something different from their placement . . . Some students do a group laboratory project focused on a specific problem, but this still involves design of experiments and individual write ups, which can be of a very high standard. (b8 F3-4)

extract 57

The students also do project work in the final year. They spend 3 days per week in the first semester working in one of the research labs. The idea is to get students to work more independently and to start to do their own experimental design. It's important that students learn to organise their own work schedule and apply themselves. It's also the first time that students get to write a full-blown scientific report, although they will have done shorter versions earlier on in their studies. It is a several thousand word report structured like a mini thesis. Some students choose to do dissertations rather than doing experimental work. This can be useful, e.g. for a student who wants to go towards a journalistic career. The students usually also get asked to speak at research group meetings which helps to develop their oral communication skills. The projects also provide an opportunity for teamwork. The students get quite a lot of support with their project, but this does vary a lot between research groups. (a7 F4)

extract 58

The students also do a project and again get a pretty free rein to choose a topic, provided that they can find a supervisor. They have to plan the project and that planning is included in the project write up; they have to provide charts of what they intended to do and of what they ended up doing. The planning process also includes the safety registration forms which the students have to complete ... The project allows the students to be involved in 'real research' they are not pre-prepared packages that will fit into a six week slot. The students usually work with a research group and contribute to the design of the project but this is usually directly related to research in the group. The expectation is that the work the students do will be of publishable standard and it is not uncommon for the students to publish, generally as one of several authors. (d5 F2)

In one instance, a substantial assignment involved students in drafting a research proposal to bid for project funding rather than conducting a full-blown project, but the intended learning outcomes were no less demanding:

extract 59

For the cell and development aspect of the course the students are asked to write a grant proposal as one of their assessments, for which they are allowed to choose the topic area in consultation with a member of staff. Before this became part of the students' final assessment, it was done as part of their training. This is a very useful task because students have to work on an area of research that is interesting, current and relevant. The students are then prompted to move to the next stage of thinking where they put hypotheses forward. To do this they must be sufficiently familiar with the literature to make reasonable hypotheses. There is a limited number of tutorials that go with the process, so the students can get a certain amount of help with e.g. developing their hypotheses. The staff member would read the first draft of the proposal, but no more than that. Previously the students also had to cost the proposal so that they had awareness, not only of what they were trying to achieve, but also of why other people would have to find that important and relevant and fundable, and also some idea of the cost involved. This has been dropped now that the proposal is part of the students' final grade, but the respondent thinks that they will reintroduce at least part of that somewhere else in the course. (d5 C1)

It would nevertheless be misleading to infer that all the assessment approaches reported could all be considered positive or optimal exemplifications of alignment. In fact, three interviewees voiced concerns about potential limitations in current assessment practices:

extract 60

The grade for the first year depends mainly on three unseen written papers at the end of the year. The biggest weakness in the first year is that I am not sure that the exams really test the skills that staff are trying to get across. In my view, they primarily test factual recall, which clearly influences the way that students learn. The argument that some of my colleagues would use (and sometimes I agree with them) is that the first year is primarily about gathering factual information and that the thinking happens later on. I worry that students may get such a strong message from this in the first year that they become convinced that factual information is what matters forever. The students are used to the A level system which primarily tests factual recall and the students they get in are extremely good at dealing with that system so they want to carry on doing that kind of exam because they are good at it. (d6 F2)

extract 61

One problem is that until the students do the exam at the end of the course they don't have any real feedback on the course. (b3 E2)

extract 62

What affects students' success more than anything else is their ability to work independently, to be an independent learner. I think this is the issue with most of the students who fail. There doesn't appear to be any correlation between A level scores and success on the programme. The most important thing is the ability of students to settle down to a pattern of working in their own time when they make the transition from a school or sixth form college to university where they have more freedom and where no one is chasing them up to do the work. One of the things the staff are focusing on at the moment is how to help the students settle down in the first semester, but we don't have an answer to that yet. We are also trying to put less weight on the first semester assessments as compared with the second semester to help with this problem, but this is difficult in a unitised system, where each unit counts equally. I think the whole sector needs to come to terms with that problem and I would welcome advice about this. (a4 E1)

3.16 Alignment of Course Organisation and Management

There were also a small number of indications of course organisation and management being viewed in relation to alignment, as in the two examples below. The first of these, which follows on from extract 36 above, raises issues of programme design within and across years of study, and the desirability of striking a balance between consistency of approach and the tailoring of strategies to reflect the differing goals and concerns of particular course units or modules:

extract 63

In the second year, instead of having tutorials, there is a series of classes of around eight students which cover different skills. . . At the moment we are considering whether to propagate this model through other parts of the course. This would be more suitable for some areas of the syllabus, whereas in other areas it might be best to remain with essay based tutorials. The department is trying to remain flexible rather than having a fixed set of ways of teaching across the whole subject – trying to let the individual course teams work out what is the best way of dealing with their subject. (d5 C4)

The second example also raises a wider issue of course management: the need not only to elicit students' views of the quality of the teaching they have received but also to respond to these promptly and constructively.

extract 64

The Department sees it as important to 'complete the feedback loops in the areas of teaching, learning and assessment', and so react to the feedback received to enable the students to better themselves. 'It works in both directions, I should say.' The approach involves student questionnaires, the results of which are published on the Department's web-site, and to which the teaching staff are required to react. Problems which recur (e.g. inaudibility in lectures, over-running the time-slot) become conspicuous because the Department posts questionnaire results – and staff responses – on its web-site. It has not yet succeeded in all three areas (particularly in relation to tapping into the learning experiences of the students) but 'that's the plan'. And since there is a Faculty TQA carried out annually, all Departments in the Faculty are expected to monitor the effectiveness of their teaching and to respond accordingly. (c10 E1)

In both of these examples (and in contrast to many of the extracts considered in earlier sections above), alignment is not linked directly to specific high-quality outcomes. Rather, it is reviewed as part of a broader consideration of system-level issues, seeking to ensure that, in Biggs' phrase, "all components in the system address the same agenda and support each other" (Biggs, 1999, p. 26). That there were few such indications of the alignment of course organisation in the telephone interviews, however, is not necessarily indicative of its relative importance in the thinking of staff, but may simply reflect the necessarily limited scope and time-span of the interviews.

4. DISCUSSION AND IMPLICATIONS

4.1 Outcomes of the literature review

In section 2 of this report, a review was presented of the literature relevant to teaching and learning in biology at undergraduate level. While national teaching assessments convey a favourable impression of the quality of teaching and learning in the subject area, it is also evident that teaching and learning processes and practices are in flux. Not surprisingly, many recent developments in undergraduate biology teaching seem to reflect the influence of demands and challenges which are common across the disciplinary spectrum. These include responding to a much-enlarged student intake with a more diverse range of backgrounds and qualifications, while at the same time coping with declining resources and heightened pressures on staff and departments towards greater research productivity. Other major challenges have been those associated with the modularisation of curricula, a greatly increased emphasis on skills and employability, the rapid pace of developments in knowledge, especially in areas such as bioinformatics, and the growth in information and communication technologies, which have brought additional costs alongside a range of new opportunities to support and manage learning, teaching and assessment.

Although there is a growing body of literature specifically concerned with undergraduate learning and teaching in biology, it is still relatively modest in scope as well as volume, focusing principally on a small number of themes. One theme has been students' misconceptions of key concepts such as photosynthesis and natural selection, and the relationships, as yet unclear, between these often persistent misconceptions and students' approaches to learning and studying. Another theme is laboratory and practical work, where the few available studies appear to point to the importance of positive and supportive interactions in laboratories, amongst students as well as between students and staff. Those studies also highlight the question of the balance struck between staff control and the degree of responsibility for their own learning that students are expected to shoulder in laboratories; indeed, there are indications of marked differences in what is appropriate for students in first and later years of study. Project work also emerges as an increasingly prominent component of curricula, particularly in the later years of study, but one where there is little hard evidence to substantiate the considerable benefits anticipated, which include a firmer grasp of the nature of scientific investigation. Similarly, the theme of problem-based learning is also one where the literature does not as yet yield a clear picture of its impact on high-level learning outcomes.

It is against this background of a small harvest of findings that the ETL project will be pursuing its investigation, with particular attention to the conceptual potential of two constructs, constructive alignment and ways of thinking and practising, in arriving at a fuller understanding of teaching-learning environments in undergraduate biology. And although there is relatively little of direct relevance in the pedagogical literature of the subject on which the project might build, both constructs do appear to have a great deal to offer. Ways of thinking and practising, as a construct, has sufficient breadth to encompass the range of high-quality learning outcomes characteristic of undergraduate biology courses, while constructive alignment could yield illuminating perspectives on those features of teaching-learning environments, including laboratory and practical work, which seek to bring about the attainment of these outcomes by students.

4.2 Outcomes of the telephone interviews

The principal findings of the analysis of the telephone interviews can be summarised as follows.

- **Teaching Orientations**

Although not directly investigated, the teaching orientations of the four departments from which the ten interviewees were drawn provide an important backcloth against which to consider how high-quality learning was conceptualised and operationalised in their interview accounts. While two of the departments appeared to be associated with a predominant research culture, all four were committed to the pursuit of research in the biosciences. A strong commitment to a professional culture characterised one department, while in another was firmly committed to wider access. These orientations seemed to be reflected in their curricula and teaching in various ways.

- **Ways of Thinking and Practising in Biology**

Interviewees' observations and reflections about high-quality learning in undergraduate biology were explored from the perspective of ways of thinking and practising in the subject. A broad distinction was drawn between forms of understanding and types of skills or competencies, in each case at a foundation and a more advanced level:

- Foundations of understanding included a sound grasp of key terms, concepts and principles, biological structures, functions and processes; and systems and levels of organisation.
- Higher-order understanding encompassed the real-world application of understanding, interconnective and synoptic understanding and epistemic understanding.
- Fundamental skills in biology included experimental and practical skills; data- analysis skills, communication skills, critical reading and bibliographic skills, and student self-regulation.
- Higher-order skills were concerned with critical evaluation and interpretation of evidence, openness to changing one's ideas, arguing a case, experimental and research project design, and reflection and debate about areas within the discipline where knowledge is uncertain or where there are contrasting interpretations

- **Constructive Alignment and the Facilitation of High-Quality Learning**

In this part of the analysis, interviewees' observations and reflections were examined from the perspective of constructive alignment, extending Biggs' model to five aspects of alignment. Indications of curricular *alignment to students* were found in the responsiveness of curricula to diverse student needs and capabilities, and the articulation of developmental perspectives on how curricula and materials might best be staged or sequenced. As far as the *alignment of teaching-learning strategies* was concerned, the active promotion of ways of thinking and practising in the subject was evident in a differentiated view of the functions of particular teaching-learning strategies, seen in interrelation, and a high valuing of tutorials, workshops and various other group-based activities in the pursuit of particular high-quality learning outcomes.

All the departments had in place mechanisms to offer students supplementary support with learning and studying. The *alignment of learning support*, however, was geared less to specific aspects of ways of thinking and practising than to the quality of student learning more generally, and so had an auxiliary role with respect to constructive alignment. And with respect to the *alignment of assessment*, what stood out from the analysis was not simply the variety of assessment methods used, but rather indications of how a given assessment method would be purposefully deployed in a particular course setting to promote and evaluate students' grasp of specific ways of thinking and practising in the subject. Projects also emerged as a prized component of final-year assessments, where they were typically used to help facilitate a cluster of high-level learning outcomes. However, some interviewees also pointed to aspects of present assessment practices which seemed to work against rather than for alignment.

Finally there was a small number of indications of the *alignment of course organisation*, but as part of a consideration of system-level course management issues rather than directly linked to high-quality learning outcomes.

4.3 Implications

It should be self-evident that, as befits pilot studies, any implications drawn from these findings are necessarily tentative and provisional. Although it will be possible to extend the literature review a little further as additional studies come to light, the corpus of available findings is not substantial enough to offer reliable wayfinders or maps of the territory. And while the telephone interviews have been fruitful in several respects, they represent a small and limited data-set. The observations and reflections which they document are those of a small number of individual members of staff, and were not triangulated against the perspectives of their course team colleagues or their students, or against other course-related data. They must therefore be treated with great caution, and valued less as data in themselves than for the insights that they can bring to bear on the focus and direction of the main phase of the ETL project.

In this latter respect, several benefits have accrued. One valuable outcome has been in underscoring the potential of ways of thinking and practising as a construct, albeit an embryonic one. It does seem to have a promising potential in capturing key subject-specific features of high-quality learning in undergraduate biology, while also encompassing a range of outcomes which traverse understanding and skills. However, it will be necessary to be alert to those forms of understanding and skills which are most appropriate to study at first and at final-year levels.

Another significant outcome has been in testing out the applicability of constructive alignment as a framework for investigating teaching-learning environments in biology, where aspects of alignment are viewed in relation to the facilitation of ways of thinking and practising as a proxy for high-quality learning outcomes. Interviews with staff proved helpful in a number of respects: in widening the range of components of alignment which need to be taken into consideration; in pinpointing the role of particular components in working for, or in some instances against, close alignment; in drawing attention to the different strategies through which alignment might be pursued; and in highlighting the extent to which alignment needs to be viewed in a highly contextualised way, i.e. in relation to the constraints and opportunities which arise within a given course setting. It will also be necessary, in Phase II, to give consideration to alignment at the programme as well as course unit level, and to the implications of the diversity of programmes of study which students enrolled in a particular course unit or module may be pursuing.

It should however be noted that the group interviews with students which will be undertaken in Phase II of the project are likely to yield crucial complementary perspectives on alignment, while also bringing to the fore discussion of issues such as engagement and feedback which have particular salience to students.

Finally, two further benefits of the pilot work can be identified. The first was that it drew our attention to the increasing availability of internet access to relevant course documentation and teaching-learning materials. While documentation in this form was only readily available in some course settings, and while its accuracy and currency could not consistently be relied upon and therefore needed to be verified, it did significantly speed up the process of familiarisation with key features of the design and delivery of a course unit. The second concerned the telephone interviews as a method of data-gathering. The interview schedule drawn up will provide a sound base from which to develop schedules for use in Phase II of the project. And although there were initial reservations about the quantity and quality of interview data which might be gathered by phone, in the event, these proved to be a productive as well as economical research tool which could also be used in Phase II in cases where face-to-face interviewing proves impractical.

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APPENDIX 1

ETL Project, Phase I

Schedule for Telephone Interviews

(to be provided to the interviewee in advance)

A. Can you tell me a little more about the students who come into this degree programme?

B. Looking at the syllabus for the module, can you pick out any particular topics or concepts which are fundamental to a student's understanding of the module as a whole?

C. Are there particular ways of thinking or specific skills which are crucial to doing well in this module? Are these also important to the discipline/professional area as whole? Are there others? How do you try to bring this about in this module? And in the degree course as a whole?

D. In this module, how easy do the students find it to acquire these key concepts and ways of thinking? Why is that? Are there particular ways in which you try to help students with any difficulties?

E. What sorts of things influence students' chances of doing well on this module? Is there anything you have been able to do within the module to help students be more successful? Study skills or other forms of support, for example?

F. Could you tell me more about the assessment procedures used in the module, and how they test the understanding and skills you mentioned earlier?

G. Looking back over the last few years, have there been any major changes in the curriculum or the way it is taught?

H. What would you like to see changed? Are there any plans in the pipeline? What scope for change is there? Is there anything in particular which makes it difficult to make any changes you would like to see made?

I. What particular aspects of the module do you feel contribute most to its success? What advice would you give to anybody else trying to develop a similar module to help them improve its quality?

J. To what extent have you been involved in TQA or QAA assessment of teaching? What is your view of the exercise? How far has it affected your thinking about teaching your courses? What about the department as a whole?

K. Is there anything else that we should be considering in our project in thinking about ways of enhancing teaching-learning environments within your discipline/professional area?