Undergraduate Learning in Science Project

Working Paper 4

Undergraduate science research projects : The student experience

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Abstract

The Undergraduate Learning In Science Project (ULISP) started at the University of Leeds in September 1994. Project members include educational researchers, lecturing staff within various science departments and others with interests in teaching and learning at the undergraduate level. The aim of the Project is to inform understanding of science teaching and learning at the undergraduate level, through a variety of research activities.

The Research Project Study was a two year ULISP research investigation into final year undergraduates experiences during project work. The results of this research study are reported in ULISP working papers 2 to 8.

This paper addresses the students' experiences of research project work. Discussion includes their views of the purpose of undergraduate projects, the process of allocating projects to students, supervision, workload, motivation, being prepared, control of project direction and experiences of the scientific research culture. Detailed reference is made to the three in-depth interviews held with each of the 12 students involved in the study, together with selections from their learning diaries. Each section is followed by discussion and interpretation of the students' views together with implications for practice. A summary of issues is provided at the start of this paper.

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Summary

The Undergraduate Learning in Science Project (ULISP) was set up in September 1994 as a collaboration between the School of Education and four science departments at the University of Leeds (Appendix 1). As part of the ULISP research programme we are investigating undergraduate learning during final year projects. This report is one of a series of working papers giving details of this study (Appendix 2).

This working paper focuses on the students' experiences of final year undergraduate projects as discussed during detailed interviews with students.

Presented below is a short summary of the main findings and issues discussed in this report.

a) Students give varying descriptions of what they want from their final year project. These include the development of their ability to organise and complete a complex task, a good mark, a test of whether they wish to do a PhD or an opportunity to apply their scientific skills to a real scientific problem. These represent the *student's educational aims* for their project. These are distinct from the *scientific aims* of the project. Supervisors could benefit from an understanding of their students' views of the educational aims of project work. (section 2)

b) Most students state a preference for projects which represent a real research problem (i.e. a project which *could* lead to new scientific insights). Students feel that such projects are potentially more rewarding and motivating. This is in spite of the fact that such projects run the risk of yielding no results or following 'blind alleys'. (section 2.4)

c) Most students were happy with the project allocated to them. However, a few students expressed confusion and bitterness about what they perceived to be an unfair system of allocating projects to students. This confusion could be dispelled if departments make clear the methods and criteria used to allocate projects to individual students. (section 3)

d) When making choices about which projects to apply for students are heavily guided by the subject matter covered in the projects. Whilst subject matter is clearly important, discussions with students nearing the end of their project show that issues such as working environment and supervision styles have a major impact on their project experience. Students could be encouraged to make choices suitable for them if such information is made available - either in the project booklet or during interviews with potential supervisors. (section 3)

e) The nature of supervision in the first few weeks of project work is crucial. During this period students benefit from discussion concerning the roles of all of those involved in their supervision (lecturer, PhD student, technicians...). In addition, supervision should take into account the fact that students are very unfamiliar with three aspects of project work: the subject area, the work pattern and the working environment. Supervisors can help by guiding reading,

establishing an expected number of project working hours and introducing students to the facilities available to them and (where appropriate) the people around whom they will be working. (section 4)

f) Misunderstandings between student and supervisor can cause students to become very demotivated about project work. The likelihood of such misunderstandings can be avoided if supervision sessions include discussion 'beyond the scientific results' e.g. discussion about the student's workload, their self-evaluation, their motivation and their plans for the project. In many cases the student prefers to discuss such issues with a third party - a fellow student or a PhD student. (section 4)

g) Many students reported that the project workload meant that their work on other modules suffered, at least at some period during their project (e.g. during the write up). Students often worked excessively long hours because of their personal desire to get results, or because of perceived pressure from supervisors and others involved in their project that long hours is what is expected of good project work. The key implication here is that student workload should become a legitimate area for discussion between student and supervisor. (section 5)

h) Whilst most students were aware of the *methods* used to assess their project (at least towards the end of their project experience) very few were aware of the assessment *criteria* applied to their work - even after their project had been assessed. Students who are aware of assessment criteria will be better able to accurately evaluate their own performance on the project - something which they are rarely able to do (section 7.2). Assessment criteria could be discussed during an informal mock assessment interview at the mid-point of project work. Such an interview could also serve as formative assessment for the student, allowing them to make informed changes to their project work. (section 6)

i) Students need to be convinced that getting no results does not necessarily mean that they will get a poor mark. Students feel that it is difficult to write a good project report without results - particularly if departments ask these reports to be written in the style of a research paper. Furthermore, students feel that they are unable to demonstrate their ability to interpret data and think creatively if they have no results to work with. Departments need to demonstrate how these issues are dealt with in the assessment process. (section 6)

j) Many of the deeper issues concerning the student's experiences of project work can be characterised in terms of their images of *themselves* and their own performance (section 7), their conceptions of their *project* (section 8) and their learning about the *culture of science research* (section 9). Outcomes from these sections are summarised in points (k) to (p).

k) Much can be done to get students psychologically prepared for the ups and downs of project work. Students in our sample have suggested that meetings with other students who have recently completed an undergraduate project would be useful (e.g. first year PhD students) - perhaps during a tutorial or seminar.

Such meetings could even help students in making their list of project choices if they were held during the year *before* project work begins. (section 7.1)

l) Many students reported becoming disenchanted or 'switched off' at some point during their project, particularly at times when results were not forthcoming, or project work was routine and repetitive. Supervisors can help by ensuring that students are *intellectually* challenged at specific points in the project. Many students complained that their project work did not encourage them to 'think'. (section 7.3)

m) Students often fail to make a distinction between *project learning outcomes* (e.g. learning to use a piece of software or finally understanding the point of a journal article) and *scientific results* (e.g. identifying the gene sequence or refining a theoretical model). This can lead to students (particularly those without results) to undervalue their achievements on project work. Supervisors can encourage students to appreciate their true progress by discussing both project learning outcomes and scientific results during discussion with the student. (section 8.1)

n) Many students fail to develop a *broader view* of their project. This includes an appreciation of how their project relates to other research and the potential applications that could follow from this research. As a result many students complain that they don't know 'what their project is about'. Students could be encouraged to develop this broader view through discussions with supervisors and presentations/essays where they explore the significance and relevance of their research area. The importance of such work could be reflected in the departmental assessment criteria. (section 8.2)

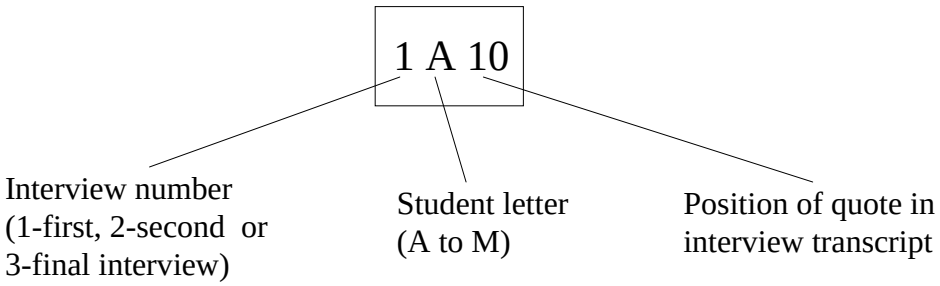
o) Students benefit from having an appropriate degree of *internal control* over the direction of their project. Supervisors could explore the student's ideas about project direction through discussion of the student's action plan or simply discussion around the theme 'what would you do next' during supervisor sessions. Whilst the student's ideas may often be inappropriate (on the grounds of cost or expense) they will benefit from the requirement to think about the direction of their project. (section 8.3)

p) Students benefit greatly from the insights that they gain about the research culture of their discipline. These insights are less evident in those students whose work takes place outside of an active research group. However, such students could benefit from situations designed to get them thinking about the research culture of which their work is a part. For example, one student reported being shown a video of a Horizon program discussing a research programme in genetics. Alternatively, students working alone could be encouraged to meet with other project students in a similar situation to discuss their experiences of science research. (section 9)

Contents

Labelling of transcript selections:

Quotes from interviews with students are presented in italics. Each quote is given a reference. For example:



1 Introduction

1.1 Research projects in the undergraduate course

In the UK virtually all science degree courses require students to complete a long-term, independent project in their final year. For the students this is a unique part of the course. Independent projects involve authentic scientific activity - often original scientific research. The student has the opportunity to gain an insight into what scientific activity is really like. Such insights are rarely gained during lecture, tutorial and teaching laboratory work.

With new experiences come new demands. Students must plan their time effectively, familiarise themselves with relevant research publications and establish a working relationship with their supervisor and other people associated with their project. There is a great deal to learn. Furthermore, these demands are very different from those associated with successfully following a lecture course or completing a laboratory practical. Students need to establish a new mode of working. In another working paper (paper 1) we describe student learning during project work as an apprenticeship. Students have much to gain from working on a 'real' scientific problem under the close supervision of an expert scientist.

1.2 The Research Project Study

The Undergraduate Learning in Science Project has undertaken a variety of studies into undergraduate learning (appendix 1). The Research Project Study is a longitudinal, case study analysis of student and supervisor experiences during project work. Full details of design and methodology are given in working paper 2. Twelve students from the four science departments involved in the project were followed over the entire period of their projects. Students were interviewed on three occasions - at the start of their project, when their project was well underway, and at the end of their project[1]. In addition, students were asked to keep a diary detailing their day-to-day experiences during project work, and occasional visits were made to students whilst they were working on their projects. Interview schedules and details of the diary are presented in appendix 3. Supervisors of these students were interviewed once when project work had been completed.

1.3 The purpose of this working paper

This paper is one of a series of eight ULISP working papers (appendix 2). Working paper 1 gives our general perspective on the teaching and learning of science in higher education. Working papers 2 to 8 report in detail on the Research Project Study. Working paper 3 gives an account of the 12 interviews with project supervisors. This paper reports on the 36 interviews held with project students. The paper paints a broad picture of the wide variety of issues evident in student's reflections about project work (see working paper 6 for

[1] Student M did not participate in the round of final interviews.

longitudinal accounts of how individual students progress through their projects). Our intention is to produce an accessible document of use to university science lecturers and others interested in teaching and learning in this area whilst reflecting the range and depth of the issues raised by students. Finally, working paper 5 also reports on the student interviews but focuses on those parts where students discuss their images of science and how these are influenced by their project work.

1.4 The structure of this working paper

The opening three sections and section 6 discuss the purpose of research projects in the undergraduate course, the allocation of projects to students, project supervision and the assessment of projects. These sections parallel the supervisors' discussions of these issues presented in working paper 3. Section 5 discusses the students' experiences of workload and time management and reflects the prominence given by students to this issue during interviews and in journal entries.

The final three sections focus on the students' views of their own performance, their conceptions of their project and their experiences of the culture of scientific research. These three sections can be characterised as the student's image of themselves, their project and science.

At the end of each section a discussion of the issues raised by the students is presented. Whilst our selective reporting of the students' reflections will inevitably involve some degree of interpretation, it is in these discussion sections where an explicit attempt is made to interpret student comments and suggest implications for practice.

2 The purpose of undergraduate project work

2.1 Projects provide an insight into science research

All students expressed the view that final year undergraduate projects represent a unique opportunity for them to gain an insight into the real world of science and science research:

> *"I think I have picked up so much from it. I have learned so much (...) even just everyday things. Just appreciate what research is all about. In a short few months you can't really get a taste of what it's really like but it's given me a bit of an insight."*
> *3E57*

> *"I guess it just gives me some idea of what being a geologist is [...] and then I guess the thought processes that you go through putting together ideas, and it's not just geologically and those aspects of life, but the way you collect your data and stuff like that that again gives me an insight into how a geologist should be."*
> *2L55*

Three distinct reasons why this is important were given.

2.1.1 Projects provide training for a future career in science research

Students were aware that a substantial number of students from their course enter science research either in industry or university. As a result there was recognition that the project provides these students with some training in science research.

> "*Well I guess with geology a lot of geology work, the oil industry and stuff like that is out being in the field, taking measurements so it's basically covering now what you could do in the future in jobs. Yes you're just doing as many different geological techniques, just getting as much data, similar to stuff that you might do in a geologically orientated job in the future. So it's good practice basically."*
> *1L43*

However, in line with the first quote in section 2.1 students were also aware that in a few months only the briefest of introductions can be given. Undergraduate projects were seen as *'a halfway house'* (1C78) or *'a link between an undergraduate and a postgraduate'* (1I77).

The following student gives a description of the kind of insights that the project will give the future research scientist:

> *"Because the understanding of Biochemistry isn't just doing Biochemistry, learning techniques from a blackboard, from a lecture theatre, you have to get hands-on experience of how all this has been found out, how it has all been deduced so you have to get - whether it be a library project or a lab project - you have to get more of an understanding of what Biochemistry actually is, because it isn't just lecture work - that's not it at all. When you get out into doing Biochemistry basically you will be working in labs if you are going into a Biochemistry field so... you have to do it because its the real world of what Biochemistry actually is."*
> *1D85*

This student believes that in order to become a research scientist it is necessary to not only have the knowledge and skills of the biochemist, but also an understanding of how the knowledge and skills are being developed. There is also a recognition that, prior to the final year, the undergraduate course has not provided students with an image of the 'world' of the scientist - the culture within which the scientist works.

2.1.2 Projects enable students to decide whether they wish to enter a career in science research

Many students looked upon the project as a chance to experience some research work before making a decision about what to do after they graduate:

> "*...it's like a real world that's been set up sort of, like a little rehearsal sort of thing."*
> *1E53*

> *"...they probably want to give us an insight into research work. They want to give us a taste of what research work is all about to make us choose, to help us choose whether we do feel that it is right for us or whether we do want to go on to do something like that."*
>
> *1J38*

Within our sample about half of the students said that their experience on the project had influenced their decision about future career. The following student realised that he was not suited to research:

> *"Well, it has influenced my choice of not doing a PhD (...) It made me a bit more aware that I wouldn't like to go into any kind of research department. Unless, I think that basically it's just too specific, looking at something very specific in science. I think I'd go mad after a while, sadly. I must have very short attention span...."*
> *3B79*

Whereas the previous student was able to make a decision informed by an increased awareness of their own abilities, the following student was influenced by the research environment within university:

> "*It certainly has influenced my decision because I came back from industry thinking (...) of a Ph.D. but then I did a project in the lab. (...) with no space and very little resources to fund any work. I found it very frustrating where it put me off science altogether, and consequently I will be leaving science at the end of this year and seeking employment elsewhere."*
> *3C113*

Finally, the following student found that experience on the project reaffirmed their commitment to continuing on to research work:

> *"I'm on a PhD (...) I don't really think that's been influenced by the project. I think it's given me more confidence in project work but I don't think it's really changed my view of what to do."*
> *3G109*

2.1.3 Projects can contribute to scientific progress

Very few students saw their research project as contributing to the progress of science. This relates to the issue of whether students felt that their scientific work was valued by other scientists (see section 8 of this paper). However, the following student did feel that their work had scientific value:

> *"...because it is some research they [lecturers] would like to do themselves but don't have the time."*
> *1F124*

One student felt that it was very important that both student and supervisor get some benefit from the project:

> *I don't think [that my supervisor] sees the point in doing a project just for the sake of doing a project (...) I think it needs to be beneficial on both sides (...) to justify doing a project.*

1E44

2.2 Projects give undergraduates a unique learning experience

Students also felt that one of the purposes of projects was to enable them to reflect back on previous undergraduate lectures and laboratory courses. In this sense projects were an important learning experience *within* the undergraduate course. This is in contrast to the first 'purpose' outlined in section 2.1 which is mainly relevant to the student *after* their course has finished.

Students often stated that projects enabled them to apply what they had learnt in previous years at university:

> *"I think it's good to put what you're learning into practice. It's all very well sitting in a lecture listening to a lecturer (...) [but] you're sat thinking well is it relevant to me? A lot of the lectures we've done have seemed completely and utterly irrelevant and sometimes you don't understand them. But then you go into the field and what you've struggled to learn for a whole semester [clicks fingers] it becomes clear like that..."*
>
> *1M40*

In working on their project this student feels that previous lecture material begins to make sense and becomes relevant when placed in an authentic context. The key issue here is the extent to which the project has improved the student's understanding of material introduced earlier in the course. In a similar way the following journal entry shows that this student feels the project has enabled her to improve her understanding of a small piece of science:

> *"General impressions about the project was that it was much better than doing a general lab. course because you have time to really understand something in a detailed way. In a lab. course, you tend to do something for the sake of following the instructions without realising why you're doing it. The talks we had to give after handing in the projects were a good idea, because it made sure you really understood what the project was about in simple terms rather than in the complicated mathematical interpretation."*
> *journalA6-7*

Although the project may not require the student to engage with a broad range of subject matter knowledge, this student appreciates the opportunity to take the time to cover a well-defined topic area in depth.

A further aspect of the project as a unique learning experience is the students' sense of being personally responsible for the work they are doing:

> *"I think it is a very good learning process in terms of organising your time how to fit the lab work in with the lectures and also thinking about things that you wouldn't get a chance to over the past two years when it was just practical work and everything was set up for you. If something didn't work [before], it doesn't matter, we get the results from the year before. But now it's like up to you, you have to make it work."*
>
> *2J28*

In a similar way the following student enjoys being forced to think and use their initiative:

> *"I keep having to think things through in my mind (...) I suppose it makes you feel that you've learnt something useful (...) You are going through it and you have to think about things yourself and remember things that you have been taught, pulling those together to make the project."*
>
> *2G70-72*

A further feature of project work was the sense of ownership and possession which many students felt:

> *"...its your little baby kind of thing and you do get really interested in one particular branch, little aspect of science, whereas if you're working on different experiments every week, every session, it's just another experiment isn't it? Nothing exciting. But [with project work] you do get into what you're doing. We all did, I think."*
> *3A103*

This student has a strong sense that the project is hers. This leads to increased motivation and interest in the project.

2.3 Projects enable students to develop their general skills

Many students felt that projects were a way of including other 'general' skills, in addition to purely scientific skills, in the undergraduate course:

> *"I would say there would be a great deal of personal development (...) certainly increased tenacity. You're going to have to stick at something - if it doesn't work just keep going. It will again strengthen the approach, logical approach to*

> *situations. Working within the lab itself obviously and in terms of presentation at the end it's going to enhance communication skills. So although it is scientifically aimed I think that the skills developed across a broad range are a lot wider."*
>
> *1C79*

Many students felt that future employers would be interested in the general skills that they had developed during their project. Projects would give students an introduction to the demands of 'real' work:

> *"[the project] has a lot do to with transferable skills. I mean I'm not exactly sure but hopefully in the job market for people like me they look at what I've done. All the data sampling (...), writing up, spending so much time on this [the project]. I guess it brings out good qualities in you that will benefit you in the future..."*
>
> *1L41*
>
> *"I think it's just virtually a chance to give you a taste of the real work, because this is it now, if I don't go on and do a PhD - big wide world time - employers."*
>
> *1E42*

The following exchange shows the extent to which acquiring general skills can be the most significant part of project work for some students:

Interviewer	*What do you think would be your best possible outcome for this project?*
Student B	*The best possible outcome?*
Interviewer	*What are you hoping for?*
Student B	*My best possible outcome would be to learn how to do 'write-ups well so that I got a decent mark for it at the end. Learn how to use computers well just as a sort of general thing for later in life I suppose. What else (...). really I mean to be honest I really would quite like to just get a good mark out of it at the end.*
	1B28-29

This student is also fully aware that the project is being assessed as part of his degree. The extent to which assessment influences approaches to project work will be discussed in section 6.

2.4 Do projects need to be real research?

In the final student interview some students were asked the extent to which they felt projects should involve 'real' research. In the context of the discussion 'real' research meant a project which could lead to new scientific knowledge. Such work was typically seen as less likely to yield results when compared with a 'safe' project.

The following dialogue was held with a student who had gathered a large amount of data on their project.

Interviewer *Would you have preferred a project that was less tightly set and was perhaps as a result more risky, in the sense that things may not have worked?*

3A110 *Yes, I think I probably would have done actually, yes. I mean, some of them were like [Richard's] and they found out new and interesting things whereas, I think its probably because mine's been done since the 1970's you know, they are going to have found out an awful lot about it whereas all his [Richard's] stuff is fairly new.*

Interviewer *Yes, but you would have preferred a new one even if it meant you didn't get any results?*

3A111 *Yes, yes, I think so yes.*

Despite having done a very successful project in terms of generating results this student would have preferred a project which could have found out new and interesting things. However in many cases 'risky' projects give no results at all. The following student had just completed such a project:

Interviewer *We've talked about the fact that there were no specific scientific findings on your project, would you have preferred a project that was more likely to get results?*

3C107 *No, not really because I think it's been a good practice, a good introduction to a whole host of techniques that I've not used before. Although the project itself wasn't successful, the general experience has been a good one. I wouldn't change that because that's why I chose the project in the first place, not because I wanted to get the [result] but because I wanted a general introduction into [the subject], which it has certainly provided.*

Despite having worked extremely hard on a difficult project this student felt that the experience had been very worthwhile.

The following student gives an additional reason why he feels that projects should address real research questions:

> *"[Projects need to be] something new, because that would inspire my interest more and it would also inspire a supervisor's interest because it's something that he'd not come across. It has got to be a good thing because he'll look it and think "I wonder why that is?" and maybe help you to suggest things you can do with that."*
> *3B77*

All three of the quotations above show students who want projects to be real research. Indeed this was the majority view across our limited sample. However, the following student sounds a note of caution and suggests a two-tier project structure:

3D90	*I had a slight disappointment that I didn't achieve a result but then, you know that's a possibility (...)*
Interviewer	*Would you have preferred a project that was more likely to get results?*
3D91	*I think it could have been more interesting in that perhaps your initial aims were set out so that you could achieve them within a decent time scale, in perhaps one and half terms and then if you had five weeks left you could have achieved something else and you would have been a lot more motivated, I think. It would have made you think a lot more about what you were doing as well.*
Interviewer	*One of the ways of making sure that projects give results is essentially to make it safer in the sense of not making it quite such front-end research. Would that suit you?*
3D92	*It would distract from it slightly if you read somewhere that it had been done before but then that has to balance with the aspect of whether you're actually achieving some results.*

The suggestion that projects start off by giving students the opportunity to get some results early on followed by a more challenging task later in the project was made by several of the supervisors (section 3, Working Paper 3).

2.5 Discussion

Students clearly feel that research projects should provide them with an authentic experience of contemporary scientific research. They do not gain such an experience from other teaching contexts such as lectures, tutorials and teaching laboratories. For many students it is during their research project that they decide whether or not to follow a career in research science (or at least a PhD). In this sense undergraduate research projects are a unique and valuable part of the university curriculum.

Beyond the science, research projects are also unique in a second way. Students are required to show commitment, time management, self-motivation and initiative over an extended period of time. No other single teaching task makes these kinds of demands of students. Many students value the opportunity to 'test themselves' in this way. Because of these demands students see research projects not just as a trial for science research but as an introduction to the demands of employment in general.

Although most students mentioned both of the above purposes, many showed a strong inclination towards one or the other. For instance, one student wanted to use the project to decide whether or not to do a science PhD whilst another wanted to get a good mark and learn how to use the computer. Students may have very different needs of project work. Supervisors and students could discuss this during the project. In working paper 3 section 2.4 it was suggested that a distinction be drawn between the *scientific* aims and the *educational* aims of project work. What is being suggested here is a discussion concerning the educational aims of the project . What does the student hope to learn?

Students generally felt that projects should involve real research. Such projects provide authenticity, motivation and are more likely to interest the supervisor (and get them actively involved). Although students are very concerned about getting results (section 7.3) many were willing to risk getting no results as long as they were involved with a real research problem. In the allocation process (discussed in section 3 of this paper, and section 4 of working paper 3) students could be made aware of which projects are risky but represent important research questions. Those students who feel it more important to get results early on then have the opportunity of ensuring that they choose such a project.

In common with students, supervisors also recognised the distinction between projects as an experience of real science research and projects as an opportunity to develop general skills (working paper 3). However, students presented an additional purpose for projects - as an extension and application of their learning earlier in the undergraduate course - particularly teaching laboratory work. For students the opportunity to 'make use of' this laboratory training is an important purpose of undergraduate research projects.

3 Allocation of Projects

In the first interview students were asked about the allocation of projects. All departments ask each student to give a list of preferences. Module managers then match projects to students, using a variety of criteria in the event of one project being oversubscribed (see working paper 3, section 4 for further details).

The table below gives the place on the list of preferences for the projects allocated to the students in our sample:

Place on list of preferences	Number of students
1st	6
2nd	2
3rd	1
4th	0
5th	1
not on their list of preferences	2
Total	12

Despite the fact that 50% of the students did not get their first choice of project (according to their recollection in the interview) only 2 students in our sample expressed reservations about the project allocated to them. Most students would have been satisfied with any of the projects on their list of preferences:

> *"...everyone was supposed to get the project that they wanted (...) but I wasn't particularly bothered. I mean I knew I had to do a project so it didn't really bother me what I did."*
> *(1C31)*

Many students also described their beliefs about how module managers allocated projects to students, particularly when projects were oversubscribed. Although students had not been told how this is done, it was clear that many had formed their own views. One student felt that it was done on a 'first come first served' basis, another that it was done 'alphabetically'. One student in particular was very bitter about the allocation process which was seen as based on academic performance in the previous two years:

> *"I know for a fact they'd gone through papers academically, people with higher grades, they got that project (...) if two people came to loggerheads over a project and wouldn't back down then, yes, the person with the higher grades they'd get it."*
> *1E18*

Students were also asked about their motivations for including the project allocated to them in their list of preferences. The table below shows the wide variety of factors used by students:

Reasons for choosing the project	**Identity of students**
I am interested in the scientific content of the project	A I F K M
I would like to work with the supervisor of this project	A
I an interested in the potential applications which could follow from this project	I J
This project is relevant to my future career	D J
I want to do a highly theoretical project	G
I want to acquire a broad range of laboratory skills	C D
I have done this sort of work before either earlier in the course or in industry	J L

The main reason given was that students were interested in the scientific subject matter covered in the project. This may reflect the emphasis given to this factor in the Project Booklets handed out to students. Another significant factor for some students was the potential for the project to yield useful applications:

> *"...it seemed quite interesting you know when I was talking about the clinical implications. I'm more interested in things that are of human or clinical implication."*
> *1J15*

Finally, in addition to some of the factors identified above, those students doing a six work stretch of field work over their Summer vacation as part of their project identified several distinctive factors:

> *"I chose this one because it was closer to home and it was cheaper to get there basically"*

> *"[I chose it for] both scientific and social reasons (..) [the social reason was] I'm guaranteed nice weather when I'm down there, because it makes it a lot easier in the field when it's not raining."*

Indeed further discussions with these students showed that isolation and financial constraints had a significant impact on their experience on their projects.

Discussion

Most of the students in our sample were satisfied with the project allocated to them so long as it was somewhere on their list of preferences. However one or two students felt very strongly that they wanted their first choice projects. Currently it is difficult for Module Managers to identify students who have a strong *desire* for their first preference project. It may be possible to give students the option of making a case on their application form if they have strong feelings for wanting their first choice project. Legitimate reasons could be direct relevance to their intended research area, or a strong relevance to their year out on industrial placement.

At least one of the students in our sample felt bitter that students with the highest exam marks are given top priority in the allocation procedure. Although this was merely a perception, it is borne out in conversations with supervisors (Working Paper 3 section 4.2). In addition there is a great deal of uncertainty amongst students about the 'black art' of project allocation. Module managers could dispel possible misconceptions by informing students of the precise methods used within particular departments. If students still feel aggrieved then the issue can be raised and discussed by the departmental staff-student committee.

The table showing the reasons given by students for choosing particular projects needs to be interpreted with care. It may be merely a reflection of the type of information available to students, rather than the sort of factors that they feel are important about projects. Indeed our discussion in section 2 shows that students feel that subject matter content is only one of the factors they consider important about projects. Other factors include whether they will have the opportunity to develop their general skills, whether or not the project is 'real' research, the extent to which they will be given the opportunity to think creatively and independently and whether the project will provide a good introduction to the life as a PhD scientist. There appears to be a strong requirement for such information to be made available to students. Whilst visits to potential supervisors would be the most suitable way of discussing these issues, not all students make the effort to do this (indeed at least one student in our sample was unable to visit any supervisors owing to her being on work placement). As a result at least some of these broader issues could be included in the Project Booklet - which is read by all students.

The process of project allocation is extremely complex. The success of the process relies on two key features. Firstly, module managers must use their skill and experience in matching students with projects in a fair way with due regard to the needs of individual students. Secondly, students must choose projects which are *suitable* for them - with consideration to their weaknesses and playing to their strengths. Since this is such a key feature of the allocation process students must be given as broad a range of information concerning potential projects as is possible.

4 The student and project supervision

4.1 Students' experiences of supervision in the first few weeks of the project

Students clearly felt that the first few weeks was a vital period for them on their project:

> *"I think the most important thing is the beginning really, the supervision at the start. (...) if [the supervisor] explains and makes sure you know what you're doing at the very beginning then you can sort of do it on your own after that."*
> *3A67*

Most students were required to prepare a 'proposal' before beginning their project work. This includes a literature review, action plan and statement of project aims. Students were required to discuss this proposal with supervisors. Some students mentioned that the proposal was an effective way of getting them thinking about their project and helped them to understand what they were doing.

Many students felt that supervisors tended to over estimate what they were capable of at the start of the project:

> *"[those involved in my supervision] just explained it to me in a sort of way where I wouldn't understand, because I don't have a clue what they are doing really, I didn't know what was going on at all and that was a bit bad. But once I had sort of worked out what was going on, once I'd read enough, things sort of clicked into place, it was very good."*
> *2B67*

For most students, working on a research project is a totally alien experience - at least at first. Some students felt that their supervisor was aware of this and that a special effort was made to relax them and make them feel comfortable with work on their project:

> *"The first thing that really put my mind at rest was [my supervisor] turning around and saying, 'Look, the first couple of weeks you're not going to know what you're doing so don't feel silly.' And, you know I made a mistake the other day and he just went, 'Oh, only the one?' (...) and, 'When we did it, it always goes wrong first time.' And the postdocs saying, 'Oh yes don't worry if it goes wrong.' That was really good because you tend to go in and think, 'I've got to get everything right from day one.."*

1E33

This student greatly valued the supervisor being aware that she was working in a very unfamiliar environment, and telling her explicitly that, at least in the first few weeks, he did not expect too much from her. The special case of settling students into the culture of a large research laboratory is discussed in more detail elsewhere in this paper.

Some students reported that they were initially very confused about the roles of other people in their supervision (e.g. technical staff, PhD student and other researchers):

Interviewer: *Has the role of those people involved in your supervision been clear to you?*

3C7 *No (...) I went into the lab and as far as I knew I was working for [my supervisor]. I didn't like to ask other people because I felt they had their own work to do, it wasn't really fair. On reflection I don't know whether it was or wasn't the situation that [the PhD student] was there to help me. In the end I had no choice but to keep asking her otherwise I'd still be in there doing it now but whether that was the right thing to do or not, I don't know. I was never told: 'If you can't do something, ask [the PhD student] because she'll be able to help you.'*

For this student at least it was taken for granted that she would ask others around her for help. However, from the student's point of view it was far from clear whether or not she could do this.

4.2 Students' conceptions of the role of the supervisor

At the beginning of their project students were asked what they felt would be ideal supervision. The responses from all students are categorised in the following table:

Student responses concerning ideal supervision

Guidance	Practical	how to do procedures	E I D A F
		has it worked?	D
		report writing	F
	Broader Understanding	keep student on the right track	J I B E C F K L
		guide reading (good/bad references)	G E A M
		help to interpret results	F G
		help prepare and assess initial 'proposal'	J D
		give a clear idea of what is expected	G C
		provide answers as an expert	M
Independence		allow student to master laboratory skills	C I
		not always checking up	C
		the chance to make mistakes in a supportive environment	E
		allow some degree of freedom with project direction	I L
Social/Interpersonal		to *listen* to the student	C
		to regularly discuss the project with student	I C E
		the supervisor to allow discussion of the student's creative ideas	G
		the student to be able to ask simple questions without feeling silly	E
Safety		- someone available in case of accident	J A

The table shows that students' images of ideal supervision vary a great deal. For instance student D feels that ideal supervision means providing him with very close guidance - particularly in how to do practical procedures. However, student I values a supervisor who will also encourage her to show a large amount of independence:

> *"I hope [the supervisor] lets me do things independently but sort of checking once in a while that I'm doing the right thing. The correct procedures in doing particular things. But not say like okay controlling you as in, you know, you should do this, this and this."*
>
> *1I37*

The third major category centred on the nature of the supervisor-student relationship. The desire to have a supervisor with whom they felt comfortable at a personal level was very strong for some students. For instance student G wanted a supervisor with whom he could hold a combative discussion:

1G54	*I'll work through [the data] myself first. I'll then go back to him and say 'Right, is this correct? Do you agree with what I've said here?', rather than 'What do I do now?' I'll try and do it myself first and then see what he thinks to what I've done.*
Interviewer	*So you'll work with the data and then ask what he thinks - and if he disagrees with what you think, what will you do then?*
1G55	*Well I'll argue my point (...) if he says it's wrong then it probably will be wrong but I'll find out why - the reasons why it's wrong and I'll explain to him what I think and then if there's a problem with my understanding of it then I'll get that sorted.*

Clearly in order to hold the kind of dialogue discussed above the student needs to feel both relaxed and confident in the presence of their supervisor. Factors which influence the nature of the supervisor-student relationship will be discussed in section 4.5.

4.3 The role of PhD students and postdoctoral researchers in the supervision of undergraduate students

Six out of the twelve undergraduates followed as part of this study found that work on their projects took place amongst other laboratory researchers (PhD students and postdoctoral researchers). All of these students valued the day-to-day technical support that these laboratory researchers gave them:

> *"As far as the postdocs and the postgrads in the lab are concerned, I've found them very helpful (...) because they have done the same experiments many times, they've got a lot of experience. In that respect I found them helpful for those technical tips because*

> *often they modify their protocol and they have these tricks of the trade."*
> *3J39*

> *"There have been separate people who can help me with the experimental side of things, which has been useful because I know one student who hasn't got any PhDs or anyone in the lab helping apart from the supervisor, which is difficult because the supervisor isn't there half the time - she's busy. So I am glad I have got people around in the lab."*
> *2D57*

The two key features identified above are that laboratory researchers have expert technical knowledge in the laboratory, and that they tend to be available on a daily basis as opposed to the intermittent availability of busy lecturing staff. Indeed many of the six students recognised that laboratory researchers and supervisors fulfil complementary roles:

> *"Basically if it is something in the lab, something say technical then I would go to the, go to one of the PhD students. But if I wanted to discuss the project overall you know how it's going, how it's gone on, maybe discuss the results then I'd go to my supervisor."*
>
> *2J23*

One student identified a problem which can occur between undergraduate project students and laboratory researchers:

> *"The Ph.D. students (...) were always there to help. They did get a bit bothered sometimes when it was time after time something was going wrong but then you can accept that, they've got their own work to do and they're busy. Generally it was a very good atmosphere, very friendly."*
> *3D58*

Clearly many laboratory researchers will have deadlines of their own and may be reluctant to commit valuable time to particularly persistent undergraduates. However, only one student mentioned this as an issue, and all students valued the supervision given to them by other researchers in the laboratory.

One of the key things that PhD students and postdoctoral researchers can give students is the chance to discuss their work informally - particularly new ideas they may have. The following student describes how informal discussions *with his undergraduate colleagues* were extremely valuable to him during his six weeks of field work:

> *"Several ideas that I had other people had had and others hadn't thought of that at all, and someone would say:*
> *'Have you thought about this?'*
> *And so it made you look at things from different angles as well, and there was always some people who had done it in some areas in more detail than you had:*
> *'Did you find this?'*
> *'Oh I didn't find that there'*
> *[...] So overall, it was a great help really."*
> *2M20*

In this case, the fact that 4-6 students live together during field work means that such peer discussions are very likely to happen. Encouraging such exchanges during term time may be more difficult. However, there is little doubt that such discussions are extremely beneficial to project students.

4.4 Students' experiences of supervision during the project

A key issue for students was the frequency of contact with their supervisor. Many students valued informal contact with their supervisor whenever it was needed:

> *"One of my friends has to actually make formal appointments with his supervisor. I mean, that's obviously because he doesn't really have the time and he's not actually there. But I think I'm really lucky (...) that I can just sort of, just say 'Ooh you know, is this right?' and 'what do you think on this?' It helps you get on with things better, you're not stuck for a couple of days, saying well I can't do anything because I don't know the answers to this problem."*
> *2E14*

However, as indicated by the student above, many supervisors are unable to provide this type of continuous supervision. In this event students felt that regular and formal meetings were required to ensure that at least some supervision occurs:

Interviewer: *Is there anything that you feel could be improved?*

2D60 *Perhaps more feedback with the main supervisor (...) perhaps a weekly discussion on where we were at because sometimes I do feel a bit confused as to what to do next (...) Perhaps I should make the effort to go and see him more. I think that would be much more [effective] if it was more a weekly thing rather than every four weeks or whatever.*

Several students felt that their supervisor underestimated the time it took them to perform tasks on the project, perhaps because the supervisor was especially keen to see progress on the project:

> *"He underestimates the time it takes to do things a bit. I went to tell him about how long it was taking me to get the software going and he sort of said 'yes, but as soon as you have got the data in the can do this and this and this' and sort of....."*
> *2F43*

The issue of effective communication is extremely important. Several incidents recounted by students appeared to be the result of miscommunication between student and supervisor. The following student initially feels that she is being put under pressure to work long hours in the laboratory and that failure to do so is seen as a lack of commitment by her supervisor:

> *"...at the beginning of the first term you are told to spend about three days in the lab. My own experience has been on the days you don't go in [I am asked] 'where were you yesterday?' which really shouldn't be the case."*
> *2C50*

> *"I just wondered sometimes did [my supervisor] actually question my commitment to his project."*
> *2C53*

However, in a subsequent interview the student comes to realise that her impressions were inaccurate:

> *"[my suspicions that my supervisor had a low opinion of me had] completely changed by the end of the project (...) When it came to the actual write up he was more than helpful in checking it and marking it and making suggestions, and so I felt if he had such a low opinion of me he wouldn't have been so helpful. It was probably my own paranoia because I wasn't getting any results and thinking it might be a reflection on me but it wasn't."*
> *3C88*

In this case ineffective communication between student and supervisor led to the student feeling undervalued through a large section of her project. The student above was receiving constant supervision. However, the nature of this supervision always centred on the technical aspects of the project. Little time was spent in discussing broader issues such as the student's feelings about the project or the student's workload. For such discussions to take place requires a

positive student-supervisor *relationship*. This is explored further in the next section.

4.5 The student-supervisor relationship: two case studies

In this section we will present brief case studies of two student's experiences of their relationship with their supervisor. Our intention is to highlight the features which influence the nature of the student-supervisor relationship by focusing on two strongly contrasting cases. Students are given pseudonyms to maintain anonymity.

The case of Ann

Ann's project was a computer based project and involved her working in relative isolation. In the very first interview Ann was aware that she found it hard to talk to her supervisor even though they met fairly regularly at first:

> *"I think that it is quite good that I can go to him when I've got problems. But, I think sometimes I would like more help but I'm a bit too shy to go and ask really."*

In the second interview the situation had not improved:

Interviewer	*The next thing I was going to ask related to your supervision, how is that going now?*
Ann	*[Pause] I find it hard to talk to my supervisor [pause] A lot of people have PhD students and so on that they can talk to and they seem to get a lot more off them than I do off my supervisor (...)*
Interviewer	*OK right. When you say you're finding it hard to talk to him is that because he is never there or is it more of an inter-personal thing?*
Ann	*Oh he's always there it's just that I feel almost a bit silly talking to him.*
Interviewer	*So it would maybe be a bit easier if, from your point of view, there were more junior researchers around like PhD students or postdocs?*
Ann	*Yes I think I could relate to them better if you know what I mean?*
Interviewer	*Yes, yes.*
Ann	*It's just that I feel so silly asking these things when it's probably just so obvious and I can't see it.*

By the time the project had been completed Ann had found it slightly easier to talk to her supervisor:

Ann *...I'd put off going to see [my supervisor] because I just felt very awkward going to see him.*
(...)
I've found it easier to talk to him than I did before.

Interviewer *Can you identify why that is?*

Ann *It's because when I went to see him in the second term I felt like I was wasting his time and he didn't want to be there, it seemed like he wanted to get me out the door as quickly as possible. When I went to see him about a problem I did it as quickly as possible so that made me a bit scared to ask him questions when I got stuck but now I force myself. I speak to him more than I did before now.*

Overall, when asked whether she was disappointed with any part of her project Ann's immediate response was 'my relationship with my supervisor'.

The case of Janet

Janet was doing an experimental project which took place within an active research group. At several points in the final interview Janet reflected on her experiences of supervision:

> *"I'd discuss with [my supervisor] intelligently (...) you could see he was quite pleased because I was thinking about what I was doing and I could see why I was doing things. So that was quite good that I could contribute in that way."*

Interviewer *How would you describe your personal relationship with those people who have been involved in your supervision?*

Janet *Quite a good relationship really, we went on a lab meal just before Christmas. I was really included in on things (...) Plus the fact that I can be quite chatty (...) So it was quite easy.*

> *"[Supervision] does come down to individual personalities (...) Some of my friends have just been completely disillusioned and absolute hate it - it has been an ordeal to the point where they just 'bunk' off time in the lab because they just wouldn't go in, because there is no point because one girl was just*

> *getting shouted at by someone in the lab. The supervisor wouldn't intervene (...) That should be monitored and there should be someone you could go to and say - 'look I am having this problem'. Not like tell-tales, but just saying 'he/she's not being reasonable, am I overreacting? Am I being too sensitive?' "*

Factors influencing the nature of the student-supervisor relationship

The wildly contrasting experiences of Ann and Janet demonstrate the complexity of issues which can influence the nature of the relationship between undergraduate project student and supervisor.

Perhaps the clearest difference between the two cases is the nature of their respective working environments. Ann found herself working in isolation. She had no contact with other undergraduate students, PhD students or postdoctoral researchers. Conversely, Janet worked on an experimental project within a large and active research group. She had a great deal of contact with PhD students. This contact with other, young researchers provides students with an approachable and readily available 'sounding board'. This can result in a friendly and motivating environment in which to work.

The second most evident feature is the differing personalities of Ann and Janet. Whilst Ann is timid and shy, Janet is ebullient and 'chatty'. It is perhaps likely that even within similar working environments Janet is more likely than Ann to establish a working relationship with her supervisor. However, in the social scene of an active research laboratory Janet excels. In this way it is clear that a key factor influencing the student-supervisor relationship is the student's personality. It is not all down to the supervisor.

However the case studies do identify a number of areas in which the supervisor can influence the nature of the relationship. In talking with her supervisor Ann felt that he was disinterested and wanted to get her 'out of the door as quickly as possible'. In contrast, Janet felt that her supervisor was pleased when she demonstrated some progress - either in terms of experimental results *or* personal intellectual development. Janet felt strongly motivated by this sense of feeling valued and praised. The key feature is the student's *perception* of being valued or otherwise. Supervisors can be interested in whether a student is making progress, but this will not motivate the student unless they are aware of it.

Whilst our analysis of the cases of Ann and Janet has shown that the student-supervisor relationship is influenced by many factors beyond the control of the supervisor, there are also some major areas in which the supervisor can have a significant influence. Furthermore, these cases show the importance of establishing a positive working relationship between student and supervisor.

4.6 Discussion

In working paper 3 we analysed the supervisors' views concerning project supervision. Section 5.6 of that paper proposed a series of recommendations for good practice in project supervision. Having analysed the *students'* views of the supervision they experienced we are now in a position to extend this discussion. In this section we will develop some of the recommendations described in working paper 3 and suggest some new ones.

A major aspect of effective supervision involves getting each student off to a good start. This enables students to develop their own independence on the project. In describing students' conceptions of ideal project supervision section 4.2 of this paper showed that students are seeking their own personal balance point between 'guidance' and 'independence'. In the first few weeks supervisors need to assess the student and where their 'balance point' may lie. This includes gaining a realistic image of what the student is capable of, particularly at the start of the project.

A further aspect of getting students off to a good start is clarification of the role of those involved in supervision. This is particularly true in those situations in which PhD students and/or postdoctoral researchers are involved in supervising the student. In some situations both student and laboratory researcher may benefit from being *assigned* to each other by the main supervisor. Laboratory researchers will then be aware that they have *some* responsibility to help the student (particularly with technical aspects of the project), and the student would be aware that they *can* ask people in the laboratory for help.

In working paper 3 we identified three features of project work which are unfamiliar to the student:

a) the subject area of the project
b) the work pattern of project work
c) the working environment of project work.

Supervision in the first few weeks involves supervisors asking questions of themselves: to what extent is the student learning about these three features?

Once the project is underway the supervision can settle down into a pattern, with regular contact between student and supervisor. This can be arranged formally or informally depending on the work patterns of both the student and supervisor. Discussion of students' views about supervision show that these supervision sessions should look 'beyond the results'. In working paper 3 we included the following quote from one of the project supervisors:

> *"I've tried to think perhaps almost more about how is the project going as a project rather than how is the science going."*

To achieve this project supervision should include such issues as student (supervisor?) workload, the intellectual development of the student, students views of whether the project is going well and what the student hopes to do later in the project. Also in working paper 3 we introduced the distinction between scientific and educational project aims. In this sense what we are advocating here is an exploration of both of these types of aims during supervision-student discussion. Whether or not this is done in special, formal meetings or informally alongside discussion of the scientific results side of the project, is again up to the supervisor and the student.

The third broad area evident in the students' conceptions of supervision presented in section 4.2 is the 'social/interpersonal' side of supervision. For some students this was a particularly important part of their conception of supervision. Again, referring back to working paper 3 we identified three features which were part of the 'human side' of supervision:

a) an awareness of the student's expectations of the project
b) making reasonable demands of the student
c) motivating the student

Our analysis in this paper allows us to consider these aspects in terms of the student-supervisor relationship. Perhaps the key message is that it is remarkably easy for students and supervisor to misunderstand each other. Discussion 'beyond the scientific results' may help to alleviate this. However, given the vast difference in experience and outlook between supervisor and student misconceptions and misunderstandings are always likely to occur. In the case study presented earlier, Ann's supervisor was unaware that Ann was disappointed about the nature of her supervision. As discussed in section 4.5 the presence of PhDs or other 'third parties' can be of benefit here. However, perhaps the key message is for the supervisor to be aware of the importance of establishing an effective working relationship with the student.

The supervision of project students is a very complex issue, the nature of which is strongly dependant on the personalities of the supervisor and the student, the working constraints imposed upon them and the working environment of the project. There is no single form of ideal supervision. In our discussion above we have tried to highlight the features which can influence the nature of supervision. Supervisors may benefit from an explicit awareness of these features, when dealing with undergraduate project students.

5 Workload and Time Management

During the second and third interviews many students identified workload and time management as a major concern. The following student was fairly typical of those students who felt that they were working longer hours than those recommended by the department:

Interviewer *How many hours a week did you find yourself working on the project?*

3D8 *Too many, to be honest. We were told at the start that we should limit to three days, the Monday, Wednesday and Friday but I found myself doing work on Tuesday and Thursday as well. It varied some weeks, but 25 hours at least. That was lab work. A heavy week would be more than that. It was a lot.*

One student reported working up to 15 hours in the laboratory on a single day and also going to the laboratory at weekends. Whilst this is an extreme case most of the students felt that the workload on project work was more than they had expected.

Given these long working hours students were asked how their work on projects affected their other modules:

> *"Things that affected the project? The time. Well I mean like last term when we had lectures it was pretty much organising your lab work around the lectures which proved difficult at times. Not extremely difficult, but it did prove difficult on certain days (...) I actually had to miss a few lectures to get the lab work done which was annoying because it shouldn't really happen that way."*
> *2D42*

Many other students admitted that their work on lecture courses did suffer at times. Many students felt that this was often unavoidable owing to the nature of many experimental procedures which may run over several days and need periodic attention. However two students did feel that there were pressures from within the laboratory to put in long working hours:

> *"I think [the workload] is quite difficult because, at the beginning of the first term you are told to spend about three days in the lab. My own experience has been on the days you don't go in [you are asked] 'where were you yesterday?' which really shouldn't be the case because it should be made obvious that third years are only supposed to spend three days. I*

> *don't know whether it was the same with other labs but I was treated very much as a post-graduate and that's what I was at the university for. Lectures can be looked at another time. So in that sense my lecture courses I haven't really kept on top of at all because, possibly if I had better results, things would have been different but I've had to keep going and going to try and generate some results."*
>
> *2C50*

In addition to a perceived pressure from within the laboratory to work long hours this student also describes a more common reason for students overworking - the personal desire to get results. This is particularly related to the students perceptions of assessment on the basis of results (see section 6).

Although most students did feel concern about their workload, some students found themselves working in laboratories which demanded a very rigid use of time - for example working 4 days per week from 2pm to 5pm. These students felt that this was how they were expected to work as undergraduates. This indicates that the nature of the research work and the research laboratory culture can have an impact on whether or not students can reasonably stick to the departmental recommendations on student time and still perform a successful project.

Another concern identified by students was the *spread* of workload over the project period. Many reported having work crises around exam times and when doing their write-up at the end of the project:

> *"Time has been a bit of a problem. That's the main thing that's hit me (...) we had exams which was a real pain because that broke the project sort of completely up - knocked me out of my stride a bit (...) since then I seem to be trying to catch up all the time..."*
> *2G46*

> *I'm panicking a bit at the moment! Work has been piled on me for the past week or so, and I've had very little spare time to do any project work. I don't think there has been any communication between lecturers of different modules to work out how best to 'spread out' work over the term. They have all given us assessed work with strict deadlines that coincide. Why couldn't we have been given some of this work earlier in the term? [...] I think that this is the most important issue that I've raised so far and is one that seriously needs addressing.*
> *journalL40-43*

Two students reported time being wasted through having to wait for important laboratory materials to arrive:

> *"Still feeling frustration at being 'held back' by forces beyond control. I am awaiting the delivery of specific chemicals before my work can proceed any further."*
> *journalC2*

Some suggestions were made by students which they felt would improve the spread of workload over the project period:

> *"I'd much prefer it if we had set working lab days and set working lecture days - I would much prefer that because you would know where you were at the time."*
> *2D43*

At least one other student felt that this would be a tremendous improvement. One of the reasons for this may be that set laboratory days would give students a very clear message that they were not expected to work any longer than this in the laboratory. A further reason may be that students can think through their project more effectively if they are able to dedicate whole days to concentrating on project work. Indeed one student suggested that the final year involve lectures, then exams and then project work and the write up. Whilst such a year does not sit comfortably within the modularised, two semester undergraduate year, this student clearly feels that having the time to concentrate 100% on project work would improve their performance.

Very few students mentioned that they had discussed the issue of workload and time management with their supervisors. This is in spite of the fact that it is clearly a major concern for project students. Furthermore many students were clearly confused about how to manage their time on the project:

> *"You don't know how much time to spend on one thing [course work] or the other [project work], you just tend to push one to the side and forget about it and be really concentrating on the other. It's hard to get the right balance between the two (...) it's really hard to tell if you are [managing you time well] because there is nobody telling you what you should be doing, but I think I am."*
> *2K44-47*

One student mentioned that her supervisor left her to organise her own time and did not consider it something that they needed to discuss:

> *"[My supervisor] was very relaxed about it and saying 'you know how much work you should be putting in so it's up to you to do that'."*
> *3E8*

Whilst many students clearly enjoyed this freedom to organise their own time, some students found the transition from rigid timetabling in their first two years to responsibility for their own time management in their final year project a difficult one.

Discussion

The question of workload and time management is a major issue for undergraduate students during their final year project. Students are being asked to organise their time over a period of around six months - a very new experience in terms of their other undergraduate work. Whilst departments make it clear to students that they are expected to work a certain number of hours on their project per week, most of the students in our sample reported a workload greater than this. The major pressures to work longer hours are the desire to get results and the need to visit some experiments periodically over a number of days. Some students felt an additional external pressure from research students and supervisors within the research laboratory. These pressures can lead students to neglect their other course work particularly at times of heavy workload (e.g. during the write up).

Some students felt that their workload could be eased if project work was separated from course work - either with separate project days or projects beginning once lectures and exams have been completed. However, departments have very real constraints on how project time can be organised within the current modularised, two semester undergraduate year.

Perhaps the key message emerging from the students concerns about workload and time management is that these issues should become a legitimate area for student-supervisor discussion. Supervisors may need to encourage students to discuss pressures from other course work. Supervisors also need to be aware of that some students may feel a very strong pressure to work ‘like a postgraduate’. This is particularly the case when students are working with research students within a research laboratory.

Research projects are a unique part of the undergraduate course. They make demands of the student rarely made in other teaching contexts. One of these demands is the need to manage time effectively over an extended period. Indeed employers leading the ‘skills revolution’ in Higher Education value a graduate’s ability to manage their time. In this sense projects are an ideal context in which students can develop this important ‘general’ skill. Indeed students mention time management as one of the things they hope to learn form their project (see section 2). Furthermore, if students are able to manage their time effectively through their project then their scientific learning across all their modules will benefit.

6 Assessment of projects

At the start of their projects students were asked about their knowledge of assessment methods. The table below gives a summary of their responses:

Knowledge of assessment methods at start of project	Students
limited knowledge of assessment methods	A B D K
the initial proposal	B
viva/interview	C J
an oral presentation to staff and students	C D E
the final report	- all students-
continual assessment of work on project	B C E G J
quality of notebooks	L M

Student's knowledge of the methods used to assess their project varied considerably. A significant feature was the extent to which students were unsure about how their projects would be continually assessed. One student felt that the supervisor would be responsible for this, though four other students said that they were unsure of how their effort over the whole project would be assessed. The situation changed towards the end of the project when departments gave students departmental documents describing in detail the methods of assessment and when these would occur.

Students were also asked about the kinds of things that assessors were looking for in student projects - the criteria of assessment. The table below shows how student's knowledge of these criteria changed between the first and final interviews:

Student's knowledge of assessment criteria	At start of project*	At end of project
limited knowledge of criteria	A B F	B F I L
the quality of results is not of central importance	C D E J K	A D J
show an understanding of what they have done and why they did it	C D J K	A G J K
regular attendance throughout the project period	D	A C K
hard work throughout the project period	J	C E J K
a systematic approach to experimentation	D	D
use of initiative	K	B E
working well with others in the laboratory		E
a development in the student's scientific ideas		G
clarity of the final report		F J

*(Students I and G did not discuss this question in their first interview)

Students have clearly developed a broader understanding of the assessment criteria towards the end of their project. However, this is largely through informal discussions with supervisors and experience of the assessment process - in the third interview students have already been assessed. Departmental documentation given to students rarely includes discussion of assessment criteria in addition to assessment methods.

The table above also indicates that students feel that the quality of the results of their project is not part of the assessment process. Indeed this is made explicit in the departmental information for students. However, in spite of this many students still have a strong desire to achieve good results on their project - to the extent that they will often spend far longer on their project work than is recommended by departmental guidelines. Students showed two reasons why this can occur. Firstly:

> *"[getting no results is] only worst in a sense that personally I haven't achieved anything, but not worst because if I had gone through all the right stages then it's beyond my control that would be acceptable in the eyes of the department."*
> *1C73*

This student has a strong personal desire to achieve good results, and had spent long hours on her project because of this. The second reason is in relation to the final report:

Interviewer	*Would you be surprised if you got a first [class mark for project]?*
3D83	*Probably, yes! To get a first I think things might have to go right, you'd get good results to start off with, then you'd have to go into a new area because you'd discovered your aims and start doing other things and you're actually thinking about it yourself.*
Interviewer	*That's interesting because that's saying to get a first you have to get the results and then be able to start directing your own work (...)*
3D84	*I'd say that [it] is unfair but I think that's how it happens. Because we had to write this report in such a strict nature, as a journal (...) and I felt that was slightly destructive.*

The student above spent a great deal of his project repeatedly following a single experimental procedure with modifications, but no eventual success. This student feels that it is very difficult to do the final write-up in the manner of a scientific report if no significant results have been obtained. This represents an indirect way in which the quality of results *does* influence the assessment.

Furthermore, getting results early on allows the student to demonstrate the depth of their understanding by taking the project forward on their own initiative, perhaps leading to a first class mark.

The final project report is a major part of the assessment procedure. In the final interview students were asked about their experiences in writing their project up:

> *"It wasn't that difficult because we'd done the proposals. In the proposal we had to give a long introduction-come-background research, so most of my introduction was done so all I needed to do was to include some extra references and some points that I hadn't included before."*
> *3J49*

The proposal was an initial statement of project aims and summary of background reading which many departments require their students to complete in the first four weeks before actual project work begins. Students also mentioned that their supervisors had shown them final reports from previous project students - this had been very helpful. Furthermore departmental information concerning the format and required content of final reports was also mentioned as giving valuable assistance.

Towards the end of the final interview students were asked whether or not they felt that their project would be fairly assessed. The large majority of students answered positively, though some reservations were expressed:

Interviewer	*I know that you don't know your final mark but do you feel that it will be fairly assessed?*
3K74	*I really don't know.*
Interviewer	*Say a bit more about that.*
3K75	*I don't think [my supervisor] really understands the amount of time I spent on my project.*
Interviewer	*In what sense? Do you think he under estimates or over estimates?*
3K76	*I think he might underestimate because I went to see him so little during the second term, whereas other people perhaps other people worked with their supervisor [more closely].*

A second reservation concerned the distinction between assessor and supervisor:

> *"[the final report] gets passed on to [the supervisor] who goes through it with a fine tooth*

> *comb and then someone who just leafs through it for the secondary mark. (...) If there's evidence that you're such great pals with your supervisor that you get a first and [the secondary marker] thinks it's not worth a first, or the other way round, if you don't get on with your supervisor..."*
> *3E54*

This student feels that the use of at least two markers will ensure that the project is fairly assessed whatever the relationship between the supervisor and the student.

Discussion

How can students be introduced to the departmental assessment of projects, including the important distinction between the methods and criteria of assessment? Many students complained of 'overload' in their first few weeks of the project. Furthermore most students only expressed concern about assessment towards the middle of their project. As a result it may be that a semi-formal question-answer session with either the project supervisor or module co-ordinator after the first 6 weeks would be useful. This could include discussion of methods, criteria and who is involved in project assessment. This discussion could be backed up with departmental documents covering the same issues.

In working paper 3 it was suggested that students be given a mock assessment interview during their project. The main reason for this suggestion was to enable the student to realise where there was room for improvement in their performance. Such formative project assessment can contribute to the student's learning during the project - encouraging them to reach their maximum potential. However, these interviews could also be used to discuss the methods and criteria of assessment with students as described above.

A very strong feature of our discussions with students was the relationship between results and assessment. In this context we take 'result' to mean significant progress towards achieving the main aims of the project (we discuss student's differing conceptions of 'result' elsewhere in this paper). Whilst most students state that they are aware that results do not count in assessment, supervisors were aware that many do not really believe this (see Working Paper 3). Our discussions with students has shown one reason why this may be the case. Some students feel that if they are held up by technical difficulties in their project then they are unable to demonstrate their full potential to interpret data, show understanding of it and show initiative in suggesting ways of taking the project forward. All of these features are seen as being required - certainly for a first class degree - but students who find an early block in their project feel that they are largely barred from demonstrating these capabilities. The message for those involved in supervision and assessment is to evaluate the departmental assessment methods in the light of this criticism, and to discuss the issue with

students - particularly those students who are working very hard but are unable to make progress on their project.

The final concern expressed by students concerns the distinction between supervisor and assessor. Students are aware that (in most cases) supervisors are heavily involved in the assessment of their project (indeed this is welcomed by most students). Some students were concerned that their supervisor was not fully aware of the amount of effort that they had put in to the project. This was particularly evident for those students working in isolation and who are unable to make progress despite their best efforts. In addition, some students felt that the nature of their relationship with their supervisor may have an influence on their final assessment. These issues are very difficult to resolve. Perhaps the key message is that assessment should involve more than one person, and that students should be made fully aware of this.

7 Students' performances on their project

7.1 Being prepared for project work

Students identified a number of aspects of their undergraduate course which they felt had prepared them for the demands of final year project work. These included mini-projects in the first and second year and laboratory work which had introduced them to the equipment and techniques used in modern research laboratories (e.g. the Polymerase Chain Reaction procedure for amplifying DNA material). One student identified 'reading research papers' as an important and useful skill which he had acquired during his previous two years as an undergraduate:

> *"...through the course we've had more and more references given to us and the references have got more complex and harder as we've gone along, which has made you read texts that maybe you don't understand fully."*
> *1G64*

> *"Often our essays ... there'll be a reading list of so many [papers] and you'll have to go and research more [papers] as well, (...) I think I was quite well, quite well prepared for it."*
> *3G107*

The same student also recognised that staff in his department had included a great deal of group work in the first two years of his degree:

> *"We have one project in the 2nd year that was very much like this, left on your own (...) and that gave me a lot more confidence. And a lot of things we do in the groups. We seem to have been doing a lot more stuff where you have to express your opinion (...) like in some of the modules we're doing group work and project work where you've got to express your own opinion and come up with answers. I've definitely learnt from that."*
> *1G70*

In addition to undergraduate work, many students also recognised that their work experience had prepared them for final year project work. Five out of the twelve students in our sample had some experience of the work place - four of these in a science based job. One of these students had taken a year out in as a researcher in a large industrial company:

Interviewer *What about your experiences in industry? How do you feel that's influenced how you've got on with this project?*

3C112 *I think for one it was a good opportunity to work in a team and although every third year is working on their own, they are part of a bigger team and you do need the people around you at various points to help. It's quite good to be able to function as a team member and be willing to help others and also to accept help. You can't do a project as much as you'd like to on your own and you've got to accept that and be prepared to accept help. Just try to become a good member of the team, even though you're only there for a few weeks.*

Significantly this student has identified the ability to accept help from members of a team as an important part of project work. Furthermore, this student received the highest project mark of those students in our sample.

Students also suggested new ways in which they could be made more prepared for project work.

Interviewer *Do you think that anything could have been done in the undergraduate course to make the project run smoother?*

3F138 *(...). Maybe a bit of guidance on how people carry out research projects.*

Interviewer *That's interesting - how could they do that?*

3F139 *I suppose by maybe getting somebody who has just done a project to come and talk to you about that or someone who's doing a PhD - talk to you about their research.*

This suggestion could be incorporated into a tutorial or seminar for second year students. Perhaps asking first year PhD students who had just completed a final year undergraduate project in the department to attend. Such a session could include other issues mentioned by students: being prepared for things not going according to the original plan, realising how long it can take to do the project write-up and considering how they can manage their time over the project.

Finally, one student mentioned that her advice to students in their second year would be to:

"Go and speak to all the people who you think you are going to do the project with, ask them if you can be shown around the lab, ask if you can be

> *introduced to a couple of people. I know that's not always practical because people could be out or whatever, but weigh up themselves - the good feeling that they get about a lab."*
> *3E62*

This student feels that students should be aware of the working and social environment in which their project will take place. This important issue is examined elsewhere in this paper.

7.2 The student's ability to realistically evaluate their performance

During our conversations with project students it became clear that some felt that they were doing very badly on their project:

> *"I suppose I allowed myself to become disillusioned with it in the second term which I shouldn't have done."*
> *3K53*

In fact this student obtained a first class mark for her project. It was only in the final interview that she became aware that in fact she had done rather well.

Part of the reason for this unnecessary disillusionment is the inaccuracy of students' self evaluations. Most students seem to be too harsh on themselves. This is often because they have unrealistic expectations of project work:

Interviewer *It must be quite daunting for someone going into a research project to feel that scientists always get things right.*

3C96 *You are led to believe that and it's only after you experience it yourself that you read of stories of postgraduates who didn't get any results until the third year of their Ph.D. But at the time you think you're the only one that can't get anything to work. On reflection it would appear that all the third years who tried [this experimental technique] didn't get any results, but you don't know that until this stage. At the time you think there's something wrong with you.*

Furthermore many students base their self evaluation on their original project aims:

Interviewer *What sort of mark do you feel that you deserve for the project?*

3I103 *On a result base, I don't think I'll get a very good grade. I didn't get enough findings. I didn't really*

> *solve most of the answers - answer most of the questions that I've raised in my proposal. And I haven't completed most of my project because I intended to do much more than I've done.*

Such an evaluation does not take into account the shifting nature of many research projects, and the complexity involved in finding an 'answer' (see working paper 5).

Many students realised that a realistic self evaluation requires communication with others. Working in isolation makes it far harder for students to be able to judge how they are progressing:

> *"It's really hard to tell if you are [doing well] because there is nobody telling you what you should be doing, but I think I am."*
> *2K47*

> *"[My supervisor's] first reaction [to my draft report] was 'you're making this sound very negative, you've got to remember that you've got some very good results. Although you've not got any sequences, there are very positive things being gained'. So I went away and looked at all the positives and found that I had a good project with positive results. It certainly did change my overall outlook because what I saw as not very relevant results, he thought they were very useful."*
> *3C86*

An accurate, positive self evaluation can lead to improved performance on projects. The following student is reflecting on what she has learnt by reflecting on her progress on her project:

> *"I think one of my strengths is that if things didn't go the way I intended them to do, initially I would get quite distressed about it but maybe I learnt to live with it, I learnt that it wasn't worth getting stressed about everything because then you wouldn't get anywhere. That is one of the things that I learnt from my project. I think just to keep on going without really letting it get to me. (...) I became more efficient and more aware of what I was doing and also more efficient in the timing. I could work faster, I could juggle time around."*
> *3J43-46*

The discussion above demonstrates how a student's self evaluation can affect their motivation, self-image, confidence and performance.

7.3 Student attitude and motivation

Students identified a wide variety of factors which they felt had either a motivating or de-motivating influence on their performance on their project:

Motivating factors

"When I started off and I got [some results] it was a pat on the back 'you're not a complete liability in the lab. and you can do something'. That was quite good for me. Because you've had some success I think you immediately take an interest." 3E16

"[project work] is something that you're not being taught straight off. You are going through it and have to think about things yourself (...) I think that makes it a bit more interesting." 2G72-73

"I felt much happier when I thought that there was some significant thing (...) [when] what I was doing had an importance and a role to play in the future." 3B28

"[I'd] try to find an area where nobody had come across anything before. Something new (...) would inspire my interest more." 3B77

"At the end of this he's going to get a [research] paper out. It's brilliant, I'd really love to do that." 3B78

De-motivating factors

"I don't get a buzz out of doing this project to be truthful. As I said it's not really the field [career] I'm really going into..." 1D72

"Not getting these results makes it very disheartening and does not exactly do too much for my enthusiasm for labwork." journalD6

"Had been working until very late (10pm to 11pm, or even later) every day and to realise that results obtained cannot be used is very upsetting and [I] felt tired and frustrated." journalI7

"At first it was very disheartening but you began to learn that's what research is about, the way you would have to repeat experiments again in different conditions, trying to get them to work (...) The motivation side - you were disheartened..." 3D65

"At the very beginning I was well motivated and then when I started to gather the data together it dropped off a bit, it was quite tedious. And then once I started to get some results and things started working the motivation increased a bit." 3F124

3L65 I found out I'm very lazy, I can't be bothered going to the library and going through reams of reports and stuff.

Int. It's that motivation thing again isn't it?

3L66 Yes. I guess it may have something to do with the fact that the report wasn't really groundbreaking stuff. If I thought people were going to actually take notice of a great deal of what I was doing [...] I would have put more work into it to try and get some answers. But as it happened didn't really need to do the research. I felt a bit guilty about not being sat in the library for hours on end but when it came down to it, it wasn't really necessary, but I still felt guilty.

Many of the factors listed here can be influenced through effective supervision. However, some are governed by the uncertainties of the research process. For instance a project may stubbornly refuse to yield results despite the best efforts of student and supervisor.

One particular factor influencing students' motivation was the extent to which they were required to think carefully about the direction that their project was taking and the implications of the results that they were getting. Students felt that 'thinking' was a very significant motivator:

> *"At the moment I do have to think about it more, and that is one thing that I do quite like, the fact that you know I have to think about what I want to change and all that. So that is quite a sort of good thing, I am quite pleased with doing that."*
> *2B82*

Conversely, some students felt that they were not required to think enough on their project:

> "*For me I was handed this [list of experiments] so I haven't had to do that much thinking at all (...) I mean I look at it and I wish he hadn't given me this [list of experiments]. I'm not going to tell him that because but I would have liked to have sort of, I would have liked him to give me an objective and to me to actually think about how I could have gone about it (...) I would have been a lot more involved than I am at the moment."*
> *1D79*

A lot of research work is routine and tedious. However, students can be strongly demotivated if this is the only part of research that they experience. This is particularly true since many students felt that projects would give them the chance to think independently and creatively, in contrast to their experiences in teaching laboratories and in lecture courses.

Discussions with students showed that how students reacted to the (de)motivating factors described above was largely a matter of individual *personality*. Some students could become enormously motivated on being praised by their supervisor or other people within a laboratory. Other students would become enthused when they came up against a difficult problem which they must think very carefully about. Some students demonstrated an impressive degree of tenacity in the face of continual 'failures' with experimental techniques. The nature of these responses is strongly dependant on the students individual personality.

7.4 Discussion

Section 7.1 shows that there is much that can be done elsewhere in the undergraduate course to prepare students for project work. One department already requires students to write reviews of a collection of research papers. This could be used by other departments as a way of encouraging students to become confident when working with research papers. Indeed members of ULISP have observed a very successful second year tutorial in the department of Earth Sciences whose explicit aim is 'how to read a research paper'.

Enabling second year students, or students at the very start of their third year project, to discuss project work with a first year PhD student could help to make undergraduates 'psychologically' prepared for the ups and downs of research. Such discussions could include typical outcomes of projects, perhaps using case studies of previous project students. Discussion could also include the length of time required to complete a write up and the importance of finding a project with a working/social environment that suits you.

The students' evaluations of their performance are crucially important. Poor self evaluation can either lead to unnecessary disillusionment or unwarranted confidence. Good self evaluation depends on having a realistic image of what can be achieved. This can come from communication with those with experience of project work - supervisors, PhD students and other undergraduate project students. Though such communication can happen informally, it may not. This is especially true for those students who are fairly isolated in their project work. More formal mechanisms which can help include group tutorials during project work. The Department of Physics at Leeds has used these to good effect. Groups of 4-6 project students meet regularly to discuss how their projects are going. Since their project are generally unrelated in terms of subject matter, students are encouraged to discuss other aspects of their projects - whether they have results, what they are worried about or their approach to the write up. Another mechanism might be mock assessment interviews for students half way through their project (as discussed in working paper 3). By introducing students to the departmental assessment criteria students will be given an image of what is expected/valued from project work. Although most students feel that departments do not give marks on the basis of scientific results they may be less aware that departments reward those students who develop an understanding of how their project fits in to a scientific research programme.

Our presentation of motivating and demotivating factors shows the kind of things which can influence a student's performance and attitude to project work. This section also shows that how a student responds to these factors is largely dependent on their personality. Whilst supervisors clearly cannot change a student's personality they can often engineer situations which can motivate students and perhaps influence their attitude to project work. An obvious example is to praise students when they have done well. Another would be to encourage and support students when problems seem insoluble. A less obvious action would be to ensure that all students have an 'intellectual challenge' at some stage during their project. Whilst opportunities for 'thinking' do crop up naturally on many projects, some students in our sample felt that this was not the case for them. An example of an intellectual challenge might be the supervisor asking a student to give him/her a verbal review of a very recent research paper which is related to the student's project. Intellectual challenges which are related to assessment criteria (e.g. developing an understanding of related scientific work) would convince students that they are an important part of their project work.

Overall, the key message from this section is that supervisors, and everyone else involved in undergraduate project work, need to be aware that the student's perceptions of their performance can be very different from how they are actually doing when compared with 'typical' project students. As a result, how the *student* is doing should become a legitimate source of discussion between student and supervisors. This is in addition to the usual topic of discussion - how the *project* is doing in terms of scientific results.

8 Students' conceptions of their projects

8.1 Students' changing images of what is involved in project work

In the first interview students were asked to describe the kinds of activities that they felt they would be involved in during their project. A summary of responses is given below.

Student's perceptions of what project work will involve (first interview)

Reading/library skills	computer searches	C J
	papers	A B C J D L M
Writing up notes		A B I L M
Practical work	taking readings/doing experiments	A J M
	repeating experiments	A
	using the computer	B F
	adapting experiments	C
Thinking	'analysing' data	A G L M
	looking for patterns in data	F
	thinking about outcomes of data analysis	G L M
	planning	C I
	how to improve/adapt experiments	C
Interpersonal/Social	working as a team	A
	weekly laboratory meetings	E
	small group talks	E
	asking questions of people to find out what they know	G

Library skills, writing up and practical work were often mentioned. However, students also identified 'thinking' and 'interpersonal/social contact' as things that they were expecting from project work. In practice some students found that what they actually did during their project was far from what they were expecting. This is particularly true for those students whose projects did not easily yield results. This mismatch will be further explored using individual case studies (Working Paper 6).

Some students were prepared for things not going according to plan:

> *"Obviously [the project] will be frustrating at times (...) but things likes this aren't set out, you know that they won't happen the way you want them to happen. Things will go wrong. So I think it's best to be prepared that things won't always go right."*
> *1J37*

The student's development of this realistic image of research work depends on a wide variety of influences. These include previous scientific work experience and activities earlier in the undergraduate course (see section 7.1).

Many students felt that achievement on a research project meant getting scientific results:

> *Possibly the most frustrating week of the project. I thought I could have been processing the data all this week but I'm still fiddling around with it, ordering it and learning how to work the computers properly. I achieved absolutely nothing.*
> *journalG6*

However, this student was learning how to use the computer system, and organising the data for analysis, both of which are important skills. Indeed in section 2 some students identified the development of such skills as a key aim of project work. Students need to be encouraged to see 'project achievements' as including computer skills, new conceptual understanding or insights into the scientific research culture, in addition to getting scientific results.

Students' understandings of 'scientific results' also changed during the project:

> *"I think I've learnt from [the project] I couldn't accept the fact that there was no proper conclusion to begin with. I was really quite annoyed with that and it took me a while to sort of accept (...) I eventually realised that there wasn't going to be a conclusion to it, so there was no point in really worrying too much about it. (...) As long as you can prove one way or another specific points either for or against and as long as you argue your case well - but you can't prove it either way - that's generally good science."*
> *3G76-78*

This student has increased his understanding of how scientists develop new scientific knowledge. He has moved away from seeing a scientific results as either a yes or a no answer to a scientific problem. Such an understanding has enabled him to appreciate the value of his scientific work. In working paper 5 we explore students' views of the nature of science and how these influence performance and develop through project work.
One student described his project using the following metaphor:

> *"Basically overall I'm very apprehensive [about the project] I see it like a kind of mountain. I can see the mountain before me and I think to myself that looks ridiculously hard to climb. I know that I will get up there but it's just like starting off it does look very daunting."*
> *1B51*

The following two students also described how they saw their project as something potentially overwhelming:

> *"Basically, I've never done anything on such a large scale, that's the longest, biggest project I have ever had to do. It's the enormity of the thing."*
> *2M11*

> *"I want to get into a rhythm fairly quickly - at the moment it still seems like I've a huge task ahead, but I'm sure that once I start it won't seem so daunting!"*
> *journalL1*

Students can feel under a great deal of pressure during project work. This can lead to some students becoming very stressful:

> *"The pressure that the department puts on you, whether or not they mean to, is a great pressure - and it's just unnecessary [...] I feel I worked a lot better in some ways without this huge weight on my shoulder..."*
> *3L94*

Students can develop very strong images of their projects. Supervisors may be unaware of the nature of these images.

8.2 The student's development of a broader view of their project

During the interviews students were asked how they saw their research project relating to other fields of enquiry. In response students identified two aspects of what we will call a 'broader view' of their project. These were the place of their work in a scientific research programme and potential applications of their work outside of the university research environment.

Many students, particularly those working within a research laboratory, gained some understanding of how their project work was related to previous work by undergraduate and PhD students, and also how their work could lead on to future research projects:

3I48 *I'm not going to be with him for the whole of the project to be completed, I'm just doing only part of the project (...) I haven't completed the whole thing (...)*

Interviewer *So after you've finished, the project carries on even though your not working on it?*

3I49 *Yeah, it's got to carry on.*

However, not all students expressed an awareness of the idea of a scientific research programme. Many students felt that their supervisor creates research projects by thinking of 'good' research questions, similar to the way they generate good examination questions, or good laboratory practicals. Not all students seemed fully aware that supervisors generally choose projects which are closely related to their own research programme.

The second aspect of the broader view identified by students was the potential applications of their project findings to areas outside of university research. For instance technological and engineering applications or advances in health care. One student felt disturbed by the fact that his project did not seem to have any such applications:

Interviewer *Have you got an image of how your work, or even the work of the group experimentally fits in to science?*

3B27 *Well that's part of the problem, actually. I find that it's like you're looking at a kind of quirk of nature. I can't really see an application of it, it doesn't seem very important or how any great thing can come of it, to be honest (...) In a sort of larger picture it's just one of those weird anomalies in that it's nice to look at but it has no real major significance.*

Students identified a number of things which had helped them to develop their 'broader view':

> *"It wasn't until after Christmas that I started looking at the papers again to form the write up and stuff that I realised the context of my project if you like. I'd already got a feel of what exactly I was doing, why I was doing it, but it wasn't really until I started looking at other papers, especially on other areas of pathway that I thought all right and then I went on and read about mammalian stuff and I thought that's why that comes in and so that was all coming together."*
> *3E16*

Many other students agreed that reading papers (especially good review papers) and preparing for the write up gave them a broader view of their project. One student pointed out that informal discussion with their supervisor did not include such issues:

> *"Any discussions I had with my supervisor or say the postgrads, it was more sort of day-to-day things and it wasn't really like you could say to him - so what's the significance of this today - because basically it's not the time for that sort of thing."*
> *3E17*

In addition to the broader view discussed above of what lies beyond their project, many students also felt that they benefited from an internal whole view of what they had achieved within their project:

> *" [I think it is important] to look at the project, as I said like stepping back every now and then to sit back and actually look back at the whole thing of what you've done (...) not get stuck in a rut sort of thing."*
> *3G65-66*

This student feels that it is important to keep a perspective on the project - the successes, failures, skills acquired and understanding developed. Such a view is important if students are to be able realistically appraise their own performance (section 7.2) and take control of their project (section 8.3).

8.3 The student's sense of control and ownership of the project

In talking with students it became clear that whilst many saw themselves as taking part in the control of their project, others felt that their project was something outside of them, beyond their control. It is this internal/external sense of control which we will examine in this section.

Some students showed a very strong sense of being in control of their project from the very beginning:

> *"I will not try and use references all the time, quoting from references. I will be trying to use my own data and with my knowledge go through it."*
> *1G106*

However, other students expressed the feeling that they had very little control over their project:

> *"...they have pretty much told me what to do and what to do next. I say [this] disappointingly, because I know other people have actually had projects they have really controlled what they have been doing they have researched what to do next,*

> *whereas I haven't seemed to be given the opportunity to do that which makes me less involved in the project - or that's how I feel - I feel as though I am doing experiments for someone else to achieve the data."*
> *2D36*

In the case above this student would have liked more control over the direction of the project. However, in some cases students seem reluctant to take control, and are content to take a passive role:

> *"At the moment I couldn't say what I was going to be doing for the next twenty weeks or however long it is going on for. I think we will be told about this as we go along what to do. So basically I haven't got a plan for the next twenty weeks. I'll just kind of know sort of week by week I think really."*
> *1A15*

This student seemed quite content to have the project controlled from outside. However, as projects progressed many students did develop the desire to take more control of the projects - to gain a sense of ownership. The following student was initially happy taking a passive role but later came to regret this:

> *"At the beginning I really wanted to be told what to do. I much preferred not to have to think about it really (...) I wish at the beginning I had an overall picture of what I wanted to do. It would have been much better than the picture of where I thought I had to sit there and be told what to do. I think it's better that you're not told what to do, that you are given the leave to do what you think will be best. That's a good thing. I wish at the beginning I'd realised that and because then I could have structured it maybe slightly differently."*
> *3B50*

Students mentioned a variety of things which encouraged them to take control of their projects. These included gaining confidence with equipment, feeling at home in the laboratory and developing a broader view of their project. One student described how he had found a research paper which his supervisor had not seen before and which had a big impact on the progress of the project:

> *"I think it gave me more confidence that I'd found something that he didn't know was there. I realised then that he doesn't really know that much more on the subject (...) than I did."*
>
> *3G38*

This student gained a great deal of confidence on realising that he was capable of controlling the direction of his project.

Finally, some students reported that they felt that their experimental equipment (or computer) was controlling their project. This was particularly the case during the periods when students were struggling to get results.

8.4 Discussion

One of the central messages from section 8.1 is that students need to be encouraged to see project outcomes as more than scientific results. Additional outcomes include acquiring laboratory and computing skills, new conceptual understanding of subject matter and insights into the scientific research culture. Such outcomes reflect the stated aims for project work reported by both students and supervisors (section 2 of working papers 3 and 4). By recognising the diversity of project outcomes students will be more likely to realistically evaluate their performance on the project (section 7.2).

In addition to a more realistic view of their project, students also need to develop an image of how their project is related to *external* fields of work. Encouraging this broader view includes enabling students to appreciate the scientific research programme of which their work is a part. Also included is the student's awareness of applications in the technological, engineering or medical worlds which are related to the their project. Students reported that preparing their write up helped them to develop this broader view. However, there may be ways of encouraging this earlier in the student's project. For instance students could give presentations (perhaps to groups of fellow students) covering such issues as 'my project and the real world' or 'my project within a scientific research programme'. There may also be ways in which such issues can be included in departmental assessment criteria.

Our characterisation of the project-student relationship in terms of internal or external control reflects a very strong feeling amongst students in our sample. Some were extremely disappointed about the lack of control that they were able to demonstrate. The task for supervisors is to recognise the degree of control which each student is capable of handling at each point in their project, and to engineer situations in which each student can develop their ability to control the project. An obvious example would be to ask the student 'what would you do next?' A more involved solution would be to encourage students to write mini 'action plans' for discussion with the supervisor, particularly at points in the project where large shifts in direction are likely to occur.

9 Learning about the culture of scientific research

Students and supervisors both identified 'getting a feel for what real scientific research is like' as one of the central aims of the undergraduate research project (Working papers 3 and 4, sections 2). In this section we will concentrate on this interaction between the student and the research culture of their discipline.

Working paper 1 gives a detailed account of what is meant by a 'scientific research culture'. This is taken to include the different roles of those involved in research (lecturers, research fellows, technicians, PhD students), the use of journals and seminars to communicate between and within research cultures, and the instrumentation of scientific research (computers, experimental apparatus, sample preparation techniques). Also included is the scientists' 'ways of thinking' about data, theories, models and hypotheses.

A huge range of scientific cultures exist. The disciplines taking part in the Undergraduate Learning in Science Project represent this diversity of research culture. Furthermore, the extent to which each student's project exposes them to the research culture of their discipline also varies. Perhaps the key issue is whether the student has access to the researchers who are working within the research programme of which their project is a part.

In this section we will examine this interaction between student and research culture. In particular we are interested in what the student is learning about scientific research through doing their project.

9.1 Students' experiences of working in an experimental research laboratory

Seven of the twelve students in our sample found themselves working within an active research laboratory. These students are working at the heart of the research culture of their discipline. In section 9.3 we will examine what they learnt about research, but first we will concentrate on how they settled in to project work within an authentic research setting.

The first few weeks can be very demanding for these students:

> *"I remember when I first started I just didn't have a clue. I went into to the lab and I just didn't know what I was doing. Because even though we've worked in the labs that kind of lab work [teaching laboratory in years 1 and 2] is totally different to when you are actually going in and doing your project. It seems really daunting at first."*
> *1J21*

> *"...you're in this lab, you've never done this kind of work before, you don't know what you're doing and*

> *nothing makes sense. Basically you're confused. But after a couple of weeks you get used to it. It's like anything new in your life - it takes a while to get used to."*
> *3J45*

Several students explained how important it was not to be afraid to ask questions at this early stage. Such questions include asking people in the laboratory where materials and apparatus are stored, how to use laboratory equipment and how to interpret their first tentative results. However, this can be difficult for students:

Interviewer *What were the most difficult aspects of the project for you?*

3E41 *The first one was just getting used to the lab and not being a complete dope because you didn't know where things were automatically. In the first few weeks having to ask someone: 'where can I find this', and then the next day saying: 'where do I find this again?'. Just give me a map of the lab and I would have been happy! I suppose that was one of my biggest problems really.*

Students are working in an unfamiliar environment amongst people who are older and far more experienced than they are. This can be very intimidating. However, most students felt that once they had got to know people in the laboratory they became more confident and were more able to ask questions when they needed to.

Some of the students benefited a great deal form the social agenda which is part of the laboratory culture - pub visits, Christmas meals and general laboratory gossiping. One student felt that this positive, sociable atmosphere encouraged her to work well on her project:

> *"I like working in the lab anyway. I like that sort of involvement (...) I've been quite lucky but I really appreciate having people I can talk to. I just can't stress how important that is."*
> *1E34*

> *"At the end of the day, I know I'll get an awful lot out of this, just (...) being part of the lab and being able to cope within a lab - to not feel silly asking questions and to realise that it is integrated, you're not stuck on your own, you're part of a group."*
> *1E39*

9.2 Students' experiences of non-experimental research

Four of the twelve students in our sample did projects which involved analysing data with the aid of a computer. Three of these students worked outside of a research laboratory. Apart from contact with their supervisor these three students worked entirely alone on their project. The following student felt that such work had little in common with a research culture:

Interviewer	*Do you think that your project will give you an insight into the work of a professional scientist?*
1K63	*I don't know. I don't think mine will personally.*
Interviewer	*No, okay. Tell me a bit more about that.*
1K64	*I think it's because I don't feel like I am doing research. I feel like I'm just playing around really - on the computer.*

Typically, the research culture of the purely theoretical scientist is very different from that of the experimental scientist. Perhaps the most significant difference is the lack of an experimental research laboratory. For students doing theoretical projects this can result in a lack of contact with active researchers in the discipline - the kind of contact valued so much by students doing experimental projects within research laboratories (section 9.1).

The other two students doing a purely theoretical project outside of a laboratory both studied in a department which has a heavy reliance on theoretical modelling and computer analysis. These students felt that their project work *did* give them an authentic experience of the research culture of their discipline. This is in spite of the fact that they had very limited contact with active researchers in their department.

9.3 What students learn about scientific research during their undergraduate projects

In the second and third interviews students described what they had learnt about scientific research:

> *"What I have learnt I suppose is the basis of scientific research (...) It wasn't a case of following a manual and having to do this exactly, there's corners you can cut and things as well."*
> *3E9*

This student has seen the human side of research - the role of creativity and intuition alongside rational thought. The same student also noted the importance of regular meetings between researchers within the laboratory to discuss each others' work.

The following student came to realise that *contacts* between researchers (especially those outside of the research group) are an important part of the research culture:

> *"Whoever is doing this [type of research] you can get in touch with them - that is what we've been doing. It's good that you've got contacts [of people who are] working in similar area but not the same area - getting ideas from them."*
> *3I40*

Many students, particularly those working within research laboratories, noted that experimental techniques *'don't always work out' (2C56)*:

> *"I think it is the sort of thing that happens in research - pretty much hit and miss whether you can get a decent result or not."*
> *2D33*

Students also came to realise that in order to get procedures to work they needed to tap into the 'craft knowledge' of experienced researchers, in addition to using information presented in research papers and laboratory protocols:

> *"I couldn't see anything that I was doing wrong (...) so I talked to the PhD students and I got a few tricks of the trade from them. Just trying to think of why it wasn't working, which it should [have done] if you were following the right procedures."*
>
> *2J12*

Overcoming such difficulties puts major demands on the character and determination of the researcher:

> *The major key to producing good research is being able to cope when things don't go too well. Thus, although the results from my project are likely to be far from ideal, the process of reaching this particular stage has been a major learning experience, and not just in terms of science. Work in the world of research demands patience and tenacity in addition to basic scientific knowledge!*
> *journalC26*

In addition, some students also felt that research work can, at times, be extremely tedious and 'boring'.

In all projects students realised the importance of reading research papers. However, understanding these papers is not always easy:

> *"I didn't know what [research papers] were saying [pause] It's quite hard to describe it really. Basically they put down all the facts in as short a space as possible and they don't actually explain - they don't explain the techniques they are using and so on because most people who read the papers they will be working with the same techniques so they won't need to explain them."*
> *2K22*

One student commented on the value of a series of lectures given as part of the research project module of in her department:

1C40	*We've been taught how to use the computers, presentation, producing overheads. Dr (...) gave a lecture on reading reviews and how to read a review and what's the best way to approach it. We had one yesterday on writing abstracts to reviews. So it's just general science skills rather than practical skills.*
Interviewer	*You've had a couple of these so far. Have you found them useful?*
1C41	*Yes very useful. (...) I mean it seems strange for someone to sit down and say this is how you read [a paper] but it's very useful because most people haven't come across reading many science big journals before so it's useful to have that knowledge.*

In addition to background reading, many students also came to realise that good research also involves a great deal of 'thinking':

Interviewer	*What are the key things you've learnt about being a scientist through doing this project?*
3J37	*Constantly you have to be thinking. In theory when you're in the lectures or seminars you're just taking in all this information without having to think for yourself - but projects, and in the research projects especially, you are constantly thinking of what's happening and how you can improve the experiment and why it's happening,*

One student was particularly surprised when his project suddenly changed direction when he stumbled upon a research paper:

> *"We [found information] in one paper that changed my project completely. That was a bit strange so I've been trying to get my head round that (...) Whether*

there is another paper out there or something that has got something else in it I don't know."

2G28

Although this student's data remained unchanged the theoretical basis of his data analysis changed overnight. The student was surprised at how influential such a 'chance find' can be in research.

Some students learnt that research cannot always give a definitive answer to the original research question. Research often yields new questions:

Interviewer *What surprised you about project work?*

3F125 *I suppose not being able to get a definite answer, things are always a bit up in the air and maybe its this - and maybe its this...*

Interviewer *Were you expecting that?*

3F126 *Yes to a certain extent I suppose I was, but even some of the questions that seemed to be quite easy to answer turned out to have a bit more to them.*

The following student has developed his view of the status and scope of scientific knowledge during his project:

Interviewer *Is there anything from the project work that has influenced how you view science?*

3B47-48 *[Scientists] only scratch the surface of knowing about things (...) When you see scientists on the telly, you are pretty sure about the way everything works (...) if you think of something scientific you think "That is definitely truth" because these people have done it and that's fact. But now I think that it's only shades of grey (...) there could be other factors which nobody has even considered yet. My view of science is not as cut and dry, it's definitely not stuff we know, it's stuff we think we know.*

Interviewer *Has that arisen directly from the fact you've done the research project?*

3B49 *Well, it's made me think about it more, to be honest. During the research project I have thought it's quite amazing what there is to know and what we don't know, in every area.*

This student has thought very deeply about the nature of scientific knowledge during his project. Another student described how she was shown a video during her project which developed her ideas about how new scientific ideas are rejected or accepted in the scientific community. The extent to which undergraduate projects influence student's views concerning the nature of science in general is examined in working paper 5.

The table below gives a brief summary of what students learned about scientific research culture during their project.

What students said that they have learned about scientific research

a) Regular meetings between researchers in a research group are important
b) Their is a role for creativity and intuition in scientific research
c) Researchers need to develop contacts with researchers outside of their group
d) Experiments do not always work first time
e) 'Tricks of the trade' are an important part of experimental work
f) Researchers require a great deal of personal stamina and resilience
g) Research work can be tedious
h) Reading research papers is very important
i) Researchers must constantly think about research direction and findings
j) Research projects can suddenly change direction in response to chance events
k) Research findings may not yield definite answers to research questions
l) Scientific knowledge is limited in status and scope

9.4 Discussion

Students whose projects take place in active research laboratories can find themselves very disorientated in the first few weeks. In section 4.1 we discussed the role which those involved in supervision have in helping the student to settle in this unfamiliar environment. Our analysis in section 9.1 has emphasised the nature of the demands on students. Students must be prepared (and encouraged) to ask questions - even very 'silly' ones. Students also need to be relaxed within their working environment in order to perform at their best. This involves a *social agenda* where everyone must get to know each other. How the student reacts to these various demands is strongly dependent on their personality (section 7). However, it is important that all people within the laboratory appreciate the demands on students in the first few weeks, and treat them sympathetically.

The experiences of those students doing projects outside of an experimental research laboratory are very different. Some students can feel that they are not doing research - especially if purely theoretical work is atypical of their discipline. However, the research culture of theoretical science is just as strong as that of experimental science, being characterised by internal seminars, discussion of research papers and informal evaluation and criticism of each others theoretical ideas. An undergraduate student is unlikely to experience such a culture during their project - particularly since there is not usually a geographical focus equivalent to the experimental research laboratory. Supervisors of such students need to be mindful of this. In particular, there may be ways of engineering discussion groups (for instance between undergraduate students doing theoretical projects) which can simulate some of the features of the theoretical research group culture.

Learning about 'real research' is a central aim of undergraduate research projects (section 2.1). In section 9.3 we identified a broad range of things which students had learned about the research culture of their discipline. Of the twelve issues (a) to (l) listed perhaps only (d), (g) and (k) could be convincingly covered within the conventional teaching laboratory context. This demonstrates the power of the open ended research project as a unique insight into the scientific research culture. It is also important to note (as emphasised in working paper 2: Design and Methodology) that we have only listed what students *said* that they had learned. Students almost certainly learned far more about science than they could explicitly identify in the course of an interview.

However, few of the twelve students in our sample have experienced *all* of aspects (a) to (l). Two students did mention ways in which 'add-on' teaching contexts had developed their understanding of some of (a) to (l) within their research project module (a lecture on 'how to read a review paper' and a video case study of the validation of scientific knowledge within a research community). One of the Undergraduate Learning in Science Project's central research questions is to what extent understanding of the scientific research culture can be incorporated into explicit teaching contexts which can complement the student's activities on their research project. Supervisors may wish to experiment with discussion groups or video case studies (e.g. from the Horizon or Equinox television series) to open up an examination of some of the issues (a) to (l) with their project students.

Appendix 1 The Undergraduate Learning in Science Project

The Undergraduate Learning in Science Project (ULISP) was set up in September 1994 as a collaboration between the departments of Biochemistry & Molecular Biology, Chemistry, Earth Sciences, Education and Genetics. It is funded by these departments together with money from the Academic Development Fund at the University of Leeds.

The aim of the project is to inform understanding of science learning at the undergraduate level. These insights will be used to improve undergraduate learning through the development and evaluation of new teaching approaches. The project has a particular interest in undergraduates' images of the actual practice of science and how these influence (and follow from) their experiences in learning science.

Departments Currently Involved

Department	Contact
Biochemistry and Molecular Biology	Dr. E Wood
Chemistry	Prof S Scott, Prof M Pilling
Earth Sciences	Prof J Cann, Dr. J Francis
Genetics	Dr. A Radford
School of Education	Dr. J Ryder, Dr. J Leach,

Further Information

If you would like further details concerning the Undergraduate Learning in Science Project then please contact Jim Ryder at the address below.

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Appendix 2 The ULISP Working Papers

As part of the dissemination of research findings to ULISP participants and others interested in teaching and learning of undergraduate science, a series of working papers has been prepared. Details of these are given below.

1 A perspective on undergraduate teaching and learning in the sciences

This paper sets out the perspective which participants in the Undergraduate Learning in Science Project have developed towards the broad range of issues associated with undergraduate teaching and learning in the sciences. The paper draws upon discussions within ULISP and is informed by the studies that ULISP participants have been involved in.

2 The Research Project Study: Design and Methodology

Focusing on the Research Project Study this paper gives an account of the design of the study. It also includes the reasons for designing the study in this way and the limitations and strengths of the data obtained.

3 Final year projects in undergraduate science courses

This paper gives an account of the role of projects and how they have been implemented in departments as discussed in the interviews with supervisors. The paper covers the suitability of projects for undergraduate work, the allocation of projects to students, supervision of students and assessment of projects.

4 Undergraduate science research projects: The student experience

This paper focuses on students' views and experiences of projects. Using interview data and entries in personal diaries a variety of issues are addressed from the student's perspective.

5 Undergraduate research projects and students' views of the nature of science

This working paper focuses on the students' views of science and science research as discussed in the interviews.. What themes are evident in the students understanding of science? In our sample of students how do views of these themes develop in time? For particular students how do their views of science develop through the research project?

6 Case studies of science students doing undergraduate research projects

Several detailed case studies from the Research Project Study are used to highlight particular features concerning research projects in the undergraduate curriculum. These can be used as a teaching resource for use in tutorials with second year students.

7 A survey of students' and supervisors' experiences of research projects in undergraduate science courses

Following from the 12 case studies reported in working papers 2 to 6 a survey was designed and administered to students (N~250) and supervisors (N~120) at the University of Leeds. Results and conclusions from this questionnaire survey are presented in this paper.

8 Implications and messages arising from the Research Project Study

This paper reflects on all of the work described above. It attempts to summarise the salient features and draw some implications of these findings for undergraduate teaching in the sciences.

Appendix 3 Interview schedules used with project students and information on the completion of log books

Interview I: Administered at the beginning of projects

A Details concerning the research project and the student:

A1 Tell me about your project, bearing in mind that I am not a specialist.
A2 Is your research project related to other work in the department?
A3 In your view what is the main aim of your project?
A4 Have you ever worked as a scientist outside of university?
A5 What do you hope to be doing after you have completed your degree?

B Project management in departments

B1 Was this project your first choice when you were deciding which project to do?
B2 What was your motivation for including this project in your choices?
B3 Are you satisfied with your project allocation?
B4 What in your view would be ideal supervision of the project?
B5 What can you tell me about how your project work is assessed?
B6 Do you feel adequately prepared to begin a research project?

C Students preconceptions about the nature of research project work

C1 Could you describe for me the kind of activities you feel that you will be involved in over the period of your research project?
C2 Which aspects of the research project do you think that you will enjoy the most?
C3 What do you think would be the best/worst possible outcome of your project.

D The purpose of research projects in the undergraduate course

D1 Why do you think that research projects are part of the undergraduate course?
D2 In your view who will be interested in the results of your project?

E Research Projects as 'real' science

E1 Do you think that your project will give you an insight into the work of a professional scientist?
E2 In what respects will your project work and the work of a professional scientist differ?
E3 How will you try to ensure that your project follows good scientific practice?

F Student's views of the nature of science in general

F1 How do scientists decide which questions to investigate? (i.e. what is the purpose of the scientific enterprise?)
F2 What is the purpose of scientific experimentation?

F3 How can good scientific work be distinguished from bad scientific work?
F4 Why do you think that some scientific work stands the test of time whilst other scientific work is forgotten?
F5 How are conflicts of ideas resolved in the scientific community?

Interview II: Administered once project work was well underway

A) What stage are you at on your project?
Ensure that this is understood in terms of the discussion about the project aims from the first interview. There may also be points from the visit which are relevant here. Follow up any new technical aspects of the project.

B) What technical difficulties have you experienced in your project? How have these problems been tackled? To what extent has the solution to these problems been within your control? To what extent have these problems impeded your progress on the project?

C) Could you describe some of the intellectual challenges that you have been faced with in your project?
E.g. thinking: the use of evidence, data interpretation, redesign of protocols, interpretation of reading, anomalies, planning of what to do next...

How have you tried to solve these problems?
Probe this in some detail - evidence of student epistemology. Use of terms such as theory, analysis, model, expected result...

D) Apart from these technical and intellectual challenges, what else has had an important impact on your progress in this project - for good or bad?
Illness/absenteeism; other university work (e.g. useful lectures, work load on other courses); interactions with other workers (personality clashes); supervision (next question)

E) How is the supervision going?
Positive points, negative points.

F) Follow up any points raised from the personal journal which have not been covered already.

G) What are your overall feelings about the project? What parts are you enjoying? What aspects do you not enjoy? Do you have any worries about the project? E.g. finishing on time, assessment...

H) Any points from the first interview which need clarifying?
E.g. work experience, a copy of the initial 'proposal'...
I) Concluding remarks

Continue to use the diary (return it to the student). Suitable period in which to do the final interview (i.e. after the assessment but not in the middle of final exams...). Does the student have any questions about the study?

Interview III: : Administered once project reports had been completed

A The research project as an introduction to the world of the research scientist

A1) I am interested in what you were actually doing during the hours that you worked on your project. What different things did you find yourself doing?
Expected factors: reading, library work, making notes in work book, writing up, doing practical work, analysing the results, planning, laboratory meetings, discussions with people in the laboratory.... - apply a hierarchical focusing strategy here.
- What proportion of the time did you spend on each of these?
- If we consider your project as a single timeline from start to finish when did you find yourself doing these things? *(Use a notepad here?).*
- hours of work per week / working at weekends?

A2) Do you feel that your project has included all aspects of scientific research work or has something been missing?

A3) What were the main findings of your project?
- use examples from the student's project as a 'hook'
- How do you know these things?
- How did you ensure that your project followed scientific practice?

A4) How important are your findings?
- Who has valued your results?
- Does your work fit in with other work - either in this department or elsewhere?
- how novel are your results?
- how have you tried to acquire a 'broader picture' of the place of your project in science?
- how has your ability to control the direction of the project changed?
- If you had an extra six months what would be your research questions?

B The student's explicitly stated views about what scientific research is in general.

B1) How do scientists decide which questions to investigate?

B2) Why do scientists do experiments?

B3) How can good scientific work be distinguished from bad scientific work?

B4) Why do you think that some scientific work stands the test of time whilst other scientific work is forgotten?

B5) How are conflicts of ideas resolved in the scientific community?

B6) In what way have your experiences on the project influenced your understanding of what scientists do?
- *probe by using the student's as described in B1-B5.*
- *what are the key things that you have learnt about being a scientist through doing this project?*

C Supervision and Assessment

C1) In what ways have your views about ideal supervision changed during the period of the project? Why have they changed?

C2) Has the role of those involved in your supervision been clear to you during the project?

C3) How would you describe your personal relationship with those people who have been involved with your supervision?
- i.e. Approachable? Encouraging? Supportive?

C4) What strengths and weaknesses did you show on your project?
- what were the most difficult aspects of this project for you?
- how did you react to working in an unfamiliar environment?
- how did your performance change over the period of the project?

C5) What do you know about the criteria which are used to assess your project?
- write up
- summative assessment of project performance

C6) How did you go about preparing the final write-up?
- did you know what to include? *(especially if limited 'results')*
- did the process of writing up change your view of the project?

C7) How did the assessment of your project influence what you did on the project?

C8) I appreciate that you do not know your final mark yet but do you feel that your project (has been/will be) fairly assessed?

C9) How would you assess your own project?

- what mark would you give your project?

D General Issues

D1) Now that you have completed the project what are your overall feelings about it?
- do you feel that it has been successful? Why?
- how has your motivation towards the project changed over the year?
- what surprised you about project work?
- what disappointed you about project work?
- how has your module work influenced your work on this project?
- would you have preferred a project that was more likely to get results or was more exploratory or 'risky'? *(as appropriate)*
- Have you been pushed to work to your maximum ability on this project?

D2) What advice would you give to a third year student who was about to begin a research project?
- what do you feel could have been done earlier in the undergraduate course to make you better prepared?

D3) *(If relevant)* Did your experiences in industry influence your approach to project work?

D4) Have your experiences on the project influenced your choice of future career?
- what is your intended career now?

D5) Are there any questions that you feel I should ask your supervisor?

Information on the completion of log books

Each student was given a journal at the end of the first interview, in the form of a board-bound A5 lined booklet. The following instructions were printed on the first two pages of the booklet, and were talked through at the end of the interview:

Research Project Study - Using Your Journal

What is the Journal?

The aim of this Journal is to encourage each participating student to keep a regular record of their thoughts, feelings and ideas about their research project.

The Journal will help you to reflect on your progress whilst providing valuable data for the Research Project Study.

All entries will be treated as confidential and will remain anonymous.

The Journal is **NOT** part of the project assessment in your department, and will only be consulted as part of the Research Project Study.

What should I write?

Anything that relates to your research project.

This could include reflections on how well you are doing, problems, successes, insights into how to do good project work, 'blind alleys' you may have followed, or even comments about the Research Project Study.

How much should I write?

As much as you wish.

We would suggest an entry every week as the minimum.

A few comments after each project session would be ideal.