Undergraduate Learning in Science Project

Working Paper 3

Final year projects in undergraduate science courses

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Final year projects in undergraduate science courses

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 science lecturer's views of the aims of final year projects, their views of the supervision of project students, project assessment and the departmental administration of projects. The paper draws upon discussions held during interviews with 12 science lecturers involved in the supervision of project students.

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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 role of undergraduate projects in the science curriculum and the implementation of projects in the undergraduate science course, as discussed during interviews with 12 project supervisors. Other working papers focus on the design of the study and the students' experiences of undergraduate projects.

Presented below is a short summary of the main findings and issues discussed in this report. These can help to frame future curriculum review within departments.

a) Undergraduate science research projects provide students with a unique opportunity to experience the actual practices of scientific research. It is unlikely that this could be achieved through other teaching contexts. Furthermore, this experience is of some value to all students irrespective of their future career plans. For instance an understanding of the often tentative nature of scientific research will encourage students to critically evaluate scientific information. Such insights are particularly important when scientific research is used in relation to health, environmental and political issues in everyday life (e.g. HIV and AIDS, or the dangers of mad cow disease). [Section 2]

b) A useful distinction can be made between the scientific aims and the educational aims of *individual* projects. One scientific aim of a project may be to throw some light on an unsolved scientific problem. The educational aims of a project are more general e.g. introducing students to the working practices of an active research group, or giving them the opportunity to communicate their findings to a scientific audience and field questions about their work. Making these educational aims explicit to both the student and the supervisor can help to increase the effectiveness of each research project as a learning experience. [Section 2.4]

c) Research project work can be usefully described as an apprenticeship which introduces students to the culture of science. Such a view emphasises the importance of working alongside experienced scientists in an active research environment. It also stresses the importance of giving students the opportunity to practice the ways in which scientific information is used e.g. reading and summarising published research papers, or evaluating their experimental results in terms of a theoretical model. [Introduction and section 3.4]

d) In the academic year before project work begins students must compile a list of projects which they are interested in doing. Departments then use this list to allocate a project to each student. Students are more likely to make *suitable* choices if they visit prospective supervisors before completing their list. Many departments encourage students to make these visits. During these visits students would benefit from a discussion of the environment in which they

would be working. They would also benefit from being introduced to some of the people with whom they may be working. [Section 4]

e) A wide variety of projects are suitable for inclusion in the undergraduate curriculum. These differ in a number of ways. For example, is the project likely to get results quite quickly or is it a fairly speculative project? Is the project undertaken within an active research group or a student laboratory? Variables such as these could be used to describe projects to students. This would help them to choose projects which match their needs. [Sections 3.4 and 4.3]

f) Supervisors can help students to settle in to project work by discussing the work pattern expected of them, the role of PhD students and postdoctoral researchers (if any) in their supervision, and by introducing them to the resources available and the working environment of the project. This is in addition to introducing the student to the *scientific* background of the project through guided reading and discussions. Aspects of these broader issues are covered by those departments which require students to prepare a protocol or work plan before project work begins. [Section 5.1 and 5.6]

g) PhD students and postdoctoral researchers might benefit from training which covers their role in supervision and provides them with case studies of the kinds of difficulties that students can face in project work. Such training can also serve as postgraduate career development. [Section 5.2 and 5.6]

h) There are some aspects of supervision which require the supervisor to take a pro-active approach. For instance, many students find it difficult to approach supervisors about non-technical issues such as whether they feel overwhelmed or worried. Supervisors can either tackle these issues directly with students or, where this is not appropriate, ensure that there is someone associated with the project with whom the student can discuss these issues (e.g. PhD student or undergraduate peer). [Section 5.6]

i) A good student-supervisor relationship is an important part of effective supervision. The development of this relationship requires the supervisor to have realistic expectations of the student, and the student to have realistic expectations of project work. The supervisor can also help by providing the student with a motivating environment, although the student also needs to demonstrate a basic level of motivation. The development of a positive working relationship between student and supervisor may be influenced by the general atmosphere of student-lecturer interaction within the department as a whole. [Section 5.5 and 5.6]

j) An important distinction can be made between assessment *methods* (e.g. viva, project report) and assessment *criteria* (e.g. ‘how much initiative has the student shown?’ or ‘has the student incorporated research findings from other workers in their project work?’). Students need to be made aware of assessment criteria at an early stage in their project. This could be done in a number of ways. For instance, mock assessment interviews could be held with students during which they are talked through the departmental assessment sheets. [Section 6]

Contents

N.B. Quotes from interviews with supervisors are presented in italics. Each quote is followed by a letter and a number. The letter identifies the individual supervisor. The number indicates where in the transcript this quote appears.

1 Introduction

This study of undergraduate research projects arises from our general interest in how undergraduates learn about the activities of scientists (working paper 1). Our research questions for the study address the supervisors' and students' views of the aims of undergraduate projects, and the interaction between the experiences of the student, supervision of students, departmental administration and assessment procedures (working paper 2). In this paper we focus on the supervisors' views of the aims of the projects, their views of the supervision of students, and the departmental administration and assessment of projects. Our discussion of these issues will include reference to detailed interviews with project supervisors.

1.1 Research projects in the undergraduate course

Most undergraduate science courses require students to do a project in their final year of study. Although the nature of these projects varies between science departments most involve an open-ended investigation into a novel scientific problem. We will use the term 'research project' to describe these activities.

Research projects are a unique part of the undergraduate science course. Students are required to work independently over several months, often amongst practising scientists within an active research laboratory. For most students the research project is their first opportunity to experience the actual practices of modern scientific research. The significance of this point is elaborated in working paper 1 of this series. In that paper it is argued that research projects allow students to appreciate both the methods of science and the social aspects of scientific research. In contrast, most other undergraduate teaching contexts emphasise the content of science - laws, theories, models, and their use. Whilst it is clear that research projects must involve some of this content, their main emphasis is in giving students an image of the actual practice of science. Such an image involves much more than an understanding of the scientific content of a discipline.

In talking of the 'actual practice of science' it is important to appreciate that there is no single scientific method to which we can introduce our students. Each science discipline will have its own character. These differences are evident in the content, methods and social relations of the discipline. Furthermore, a short term undergraduate project can only hope to include a few of the many activities which a professional research scientist would be involved in. As a result we can expect students' experiences on research projects to vary a great deal both between and within disciplines. However the key point remains. All students will experience a part of what it means to be a practising research scientist.

1.2 Research projects and undergraduate learning

Work within the ULISP research program is informed by a particular view of undergraduate learning in the sciences. This view is detailed in working paper 1 of this series. In summary, our approach centres on two key features. Firstly, rather than the transmission of knowledge from active lecturer to passive student, effective teaching and learning involves a communication of ideas between lecturers and students. Secondly, in investigating this communication between the student and the lecturer the nature of the subject matter itself is crucially important. Science is a unique discipline. It places distinctive learning demands on the student which can only be appreciated by reflecting on the nature of the discipline itself. This feature of undergraduate learning in the sciences is explored further in working paper 5.

One reason for our interest in research projects is that both of the key features identified above are strongly evident. Research projects involve a great deal of communication between the supervisor and the student. In many projects the student is also required to work closely with postgraduate students and post-doctoral fellows. Furthermore the nature of the discipline itself features very strongly in research projects. Many students find themselves working alongside professional scientists on a problem of immediate interest to the scientific community. Many of these features can be captured by viewing student learning on research projects as an apprenticeship into science research. Students are working within a research institution under the close guidance of a professional research scientist. They have the opportunity to talk to research scientists and find out how a professional tackles a research problem. Students can then use what they learnt to guide their own research work. This process of *enculturation* is elaborated in working paper 1. Throughout this working paper we will draw upon this view in discussing the role and implementation of research projects.

However, our use of the term enculturation need not imply that the sole purpose of undergraduate research projects is the training of future research scientists. The process of enculturation gives students a deeper understanding of the nature of their science discipline. Such insights are of value to all students whether or not they become professional research scientists. Science journalists, politicians and teachers can all benefit from an appreciation of the nature of their subject.

1.3 The research project study

Full details of the design and methodology of this study are given in working paper 2. The longitudinal study follows 12 undergraduates and their supervisors. Students are interviewed on three occasions and asked to keep a diary during their project. In addition they are visited at various times whilst working on their project. Supervisors are interviewed at the end of the project and departments provide official documentation relating to the implementation of projects in their departments.

ULISP research studies are based on an action research model (working paper 2). This involves the continuous cycling of findings between educational researchers and practitioners in science departments. Regular workshops are held where

practitioners are able to discuss preliminary findings with researchers. Outcomes from these workshops form part of the data set for the study.

Working papers 3 to 8 report on different aspects of this study. In this paper we address how departments and project supervisors view the role of the undergraduate research project in the curriculum, and how projects are implemented by departments. Other papers in the series discuss students' accounts of their experience on research projects, case studies of particular projects, students' views of the nature of science and educational implications arising from the study (Appendix 2).

In discussing the role and departmental implementation of projects this report is based mainly on selections from the full transcriptions of the responses given in the interview with supervisors. This interview schedule is given in Appendix 3. Further data is drawn from workshop sessions with science teaching staff and official departmental course information (see working paper 2 for further details).

1.4 The structure and purpose of this working paper

The following five sections each focus on a particular aspect of the implementation of projects by departments. Each section begins with a characterisation of the supervisors' responses. This characterisation necessarily involves a degree of interpretation on the part of the researchers. However the overall aim is to give a descriptive account of what supervisors said. Each quotation is given a letter representing the supervisor and a number giving the position of the quote in the original interview transcript. This characterisation is followed by a discussion section which brings out the distinctive features and provides a critique of the supervisors' responses, drawing on discussions from workshops and departmental literature.

The intention of this working paper is to provide an account of the variety of conceptions of project purpose, type, supervision, allocation and assessment held by individual staff members. Such a descriptive account can itself lead teaching staff to question their own practice leading to changes in the implementation of projects in departments. Indeed this is one of the purposes of action research. In addition the discussion sections provide a series of recommendations concerning the future development of undergraduate project work. These tentative recommendations are presented in the summary at the start of this working paper.

Future ULISP activities will include the evaluation of changes to departmental practice. However perhaps the most important outcome of a research study such as this is the change in the conceptions of those involved in the research, and the resulting effect this has on their own practice. In the words of one science lecturer:

> *"I think it's been very important that we've looked at [projects] not just as a science (...) that we've been*

encouraged to think more about the processes that we are trying to develop and so forth. It would have been easy not to do otherwise with other pressures. I think it's been impossible for me to work this year without having this feeling of 'I'm involved in [ULISP] I must reflect a bit more carefully on that'. "

2 The purpose of research projects in the undergraduate curriculum

Setting up and supporting final year undergraduate projects is both expensive and time consuming for departments. Given the financial constraints that departments face and the recent increases in student numbers within departments, it seems pertinent to ask why undergraduate research projects are part of the undergraduate course and whether they are worth the time and money invested in them. A related question is whether or not the things that undergraduate research projects offer can be included in other teaching contexts such as special tutorials or lecture courses.

In this section we will examine the supervisor's responses to the question "What do research projects contribute to the undergraduate course?". Responses indicate two major areas covered by undergraduate research projects. Firstly they are an introduction to 'real scientific research work'. Secondly they provide an opportunity for students to develop their 'general skills'.

2.1 Undergraduate research projects as an introduction to real scientific research

Responses from the supervisors show a very strong emphasis on undergraduate research projects as being an important introduction to the real world of scientific research. Indeed many see the project as the only opportunity in the undergraduate course for students to learn about real scientific research. The supervisors' responses cover three issues in this area. Firstly, why is it necessary for students to learn about real scientific research. Secondly, how do undergraduate research projects enable students to gain an understanding of scientific research. This aspect is covered in section 3 of this working paper. Thirdly, what is it about real scientific research that supervisors want students to gain an understanding of.

2.1.1 Why should students learn about real scientific research work?

As training for future work as a scientific researcher

Supervisors are aware that around 50% of their students go on to do scientific research either in universities or in industry. Projects are seen as vocational training for such a career:

> *"[Research Projects] are a major part of training of a scientist (...) So, for us to turn out someone with a science degree without having had some experience of this, I think we'd be selling them a bit short and particularly in a department like this where a good half of our graduates go on into research careers..."*
>
> (K1)

Research projects enable students to decide whether they wish to embark upon a research career

On entering the final year the concerns of most students will be centred on their future careers. Indeed, given the current state of graduate employment prospects, many will have had discussions with careers officers in their second year. Supervisors are aware of this concern about career prospects and see the research projects as an opportunity for the student to make an informed decision as to whether a research career is for them:

> *"...you can give them an opportunity [to decide] whether they want to be in research or not. They will assess through themselves their potential, and it will tell me how Miss X or Mr Y will fit into a future research programme. You know, will they have problems, how do they do it and these kind of things. So it is if you like a pilot pre-career programme for them."*
> *(I1)*

An authentic view of scientific research is also valuable in careers which are science related but do not involve actual scientific research

There was an awareness that even where the student may not enter science research there are science related careers in which it is useful to have an understanding of real scientific research work:

> *"...and even if they're not in the laboratory, if they're medical reps., it is still very useful to know what goes on so that you can talk to people meaningfully."*
> *(E1)*

Although not explicitly mentioned by supervisors in the interviews this point might apply to other careers such as science journalism, science policy formulation, science teaching, medical practice, industrial product development and the marketing of scientific goods. Roughly 20% of students from participating departments enter employment in these areas.

Giving science students an authentic image of scientific research is reason enough

Science is a great cultural achievement. Many students choose to embark upon an undergraduate science course because they have been impressed and excited by science at school, or perhaps by media coverage of great scientific achievements. For these students this initial enthusiasm may not be satisfied by lectures, problem classes, tutorial work and exams. Undergraduate research projects represent a chance to reward the student's hard-earned 'apprenticeship' by getting on to the 'real thing', the original source of their excitement and

interest. Such a view is evident in many of the responses from supervisors. It is almost as if supervisors wish to share with their students what **they** find is so fascinating about science.

> *"I think it gives them a really excellent opportunity to feel inspired, if you like, to feel that they are contributing something to the subject. To get involved and not just ticking off twenty credits, and getting somewhere so they've got a chance to express themselves but also, you know, feel involved in research and the subject. You know they're doing [this subject] for a reason. They can start to get a flavour of it I think when they do that. That's the most important thing as I say is then getting a sense of being in the research part of the subject."*
> *(F1)*

There is the feeling that anybody who leaves a science degree without having had some experience of the actual practice of science has been cheated. As quoted earlier:

> *"So for us to turn out someone with a science degree without having had some experience of [research], I think we'd be selling them a bit short..."*
> *(K1)*

2.1.2 What can students learn about real scientific research work by doing an undergraduate research project?

We have already described why supervisors feel that it is important that students learn about real scientific research work. Typically the supervisor then goes on to say exactly what it is about scientific research that they want their students to learn from the research project. Furthermore the supervisors were also asked the question "What can undergraduate research projects tell students about the work of a scientist?" later in the interview schedule. In reporting on the supervisors responses to these issues it is useful to represent science in terms of three distinct aspects:

i) Scientific Knowledge
ii) The Methods of Scientific Enquiry
iii) Scientific Culture

Although these categories are useful in presenting the responses of supervisors, and are commonly used in the literature on science studies, they cannot be said to have emerged from the interview data (see Working Paper 1).

Scientific Knowledge

This aspect is taken to include both the scientific information itself (scientific content knowledge) and the nature of scientific knowledge in general. The extent to which research projects can give students a better understanding of scientific content knowledge was mentioned by very few supervisors. This may be due to the very narrowly defined content area of most projects. However several supervisors felt that research projects do enable the student to begin to see the nature of scientific knowledge:

> *"I think what we really hope is that it teaches them to be much more critical in their attitude to all scientific information. They realise how, in a sense almost arbitrary, are the criteria we use to assess meaningfulness and adequacy and how they are in a sense not some absolute or philosophical concepts, they come to reflect consensus of the best work in the field."*
> *(J15)*

This supervisor is expressing the view that scientists need to make choices about the meaning and reliability of scientific knowledge and that such decisions are not based on universal scientific criteria, but arise from agreement within the community of workers in the discipline. It is this view of scientific knowledge which the supervisor hopes the student may develop through project work.

The Methods of Scientific Enquiry

This aspect involves what science researchers actually do. It includes both the 'mechanism' of doing research and the practical knowledge which researchers must develop. The following two quotes illustrate that supervisors firmly believe that the research project will enable the student to learn about the *process* of doing research:

> *"Yes, they personally collect their own data, they personally research into the data. Jumping forward, they produce a detailed report which they don't do elsewhere so there's the writing up of their observations and the interpretation of their observations which they don't get elsewhere. And the whole mechanism of research I suppose in collecting data and having a reasonably open ended project over which direction to go to complete their project."*
>
> *(G3)*
>
> *"They appreciate firstly the overall strategy of scientific work, of identifying the problem, planning a strategy to solve it, designing the experiments - I am talking about experimental projects but of course much the same will occur say for a computer-based project - designing the experiments, carrying them*

> *out, interpreting the results if any, troubleshooting if the results are not usable, interpreting the results if they are usable and then using them to assess the current state of the problem and going on to the next bit of work to solve it."*
> *(J3)*

The following quote is typical of the many supervisors who feel that the 'hands-on' aspect of projects as an opportunity for students to gain 'craft knowledge' in their subject - the ability for instance to gain practical skills:

> *"...in an active research group they can actually get the experience of someone who's actually using this technique and tell them, you know, 'you have to do it this way' or 'you have to do this at this point' or 'that's not quite right...if you give it six minutes instead of five you'll find it works but otherwise it won't'. It's sort of the witchcraft element, the personal experience element that...they have to pick up..."*
> *(K2)*

The 'witchcraft element' implies that much of what makes experiments work cannot be written down explicitly but comes from experience and in time becomes an implicit but vital capability of the scientific researcher.

Scientific Culture

In the literature on the study of science this aspect represents the 'world' in which science researchers work. It includes the people with whom they work, the professional institutions to which they belong, the bodies from whom they obtain their funding and what must be done to become established as a research scientist i.e. the career pathways available to novice researchers. This aspect can also include how the 'scientific culture' interacts with other cultures and society in general i.e. ethical issues, legal issues and communicating science to the broader public.

Whilst not explicitly talking in terms 'scientific culture' supervisors are clearly aware that undergraduate research projects enable the students to become more familiar with the 'world' of science research. In terms of communicating science to the broader public:

> *"I mean [the project] has got a reason to it and it wasn't just looking at earthquakes for fun (...) We are after all doing a social science really. I mean, you know, earthquake hazards, oil exploration, test band monitoring, you know seismology has got a reason and I like them to try and you know, if they do nothing else by the time they finish at Leeds, they*

> *should go away and be able to tell their family what's the point of this subject. So there is, there is a kind of social side too."*
> *(_44)*

The following two supervisor are talking about how projects give the student an image of the realities of working amongst people in a research group:

> *"...they can get the possibility of going into an actual research lab. and experiencing within an active research group what its all about, the pitfalls, the trials, the tribulations as well as the excitement whilst on the research."*
> *(D1)*

> *"Well, it can tell students about how a scientist has to work, and it knocks out of their heads, once and for all, this glamorous image. Up until then they might have thought that science was all glamour. Once they realise it's 95% routine idiot work and it's the 5% you're looking for that really makes it all worthwhile. They then have an appreciation of what it is to be a scientist."*
>
> *(K19)*

The following supervisor is talking about the role of research publications in science, and the extent to which a project student can learn that they can often hide as much as they say:

> *"Well it gives [students the opportunity to] (...) discover what the people who publish these techniques don't actually say."*
>
> *(K2)*

Finally, one supervisor stated that students can gain an understanding of the key problem areas in their discipline through undergraduate project work but that this depended partly on the content of the rest of the undergraduate course:

> *"The total significance is partly dependent on how we couch the rest of the course. If we teach them where the problem frontiers are then they know whether they're moving them back or not or forward [...] that's partly up to the supervisor at an early stage to help [the student] define that."*
> *(L26)*

These responses reflect the belief that research projects can give students an image of science that is based on their actual experience of science in practice. In this sense the student gains a more authentic image of science as a human activity through project work.

2.2 Undergraduate research projects enable students to develop their general skills

Although supervisors mostly emphasised that undergraduate research projects provide students with an experience of real scientific research, many were fully aware that students would also have the opportunity to develop their 'general skills' during the project:

> *"One of the learning processes for them I think is just time management and self motivation and those are two big things that they have to learn about."*
> *(M62)*

> *"I think that there are a lot of skills in an independent project like this that are transferable to lots of jobs and or situations where they need to make decisions about what they are going to do, how they're going to respond, how they're going to plan their time."*
> *(L56)*

These general skills are clearly of benefit to all students, but for those students not going into science research or a science related career they are particularly relevant:

> *"...even if they're going to organise the baked beans in Marks and Spencers, I think it gives them practical organisation (...) so partly I think it's just general practical acumen, organisation."*
> *(E1)*

> *"I think it's quite clear that the project has to play a lot of roles. It's not just that they need to develop their skills at the bench. It was the first opportunity for our students really to go to the library and look at anything other than an undergraduate text book. It was the first opportunity for them to make presentations, have to read papers, think about them and then tell a few people about them and so it has been a very useful medium for us to introduce these additional skills."*
> *(A5)*

The following supervisor feels that there are many ways in which general skills can be included in the undergraduate curriculum but that research projects provide a relevant context in which these skills can be incorporated.

> *"...the most important thing (...) is getting a sense of being in the research part of the subject but obviously internally they've got the chance to*

> *develop analytical skills, critical skills that aspect of them, which we could do in other ways but I think the research directed projects are a real good one."*
>
> *(F1)*

Projects also provide a context in which students can develop a sense of ownership. This can often lead to enhanced motivation for some students:

> *"[In our department] they're very important because they are the one piece of work that the student does for themselves, by themselves, that is their piece of work and they're very proud of possessing it."*
> *(M3)*

A further aspect mentioned by supervisors was the demand from employers for graduates with well developed all-round abilities:

> *"You know we see the results of something produced with Lucas by the University of West Midlands - the top fifteen things that external employers want from a student. Number one was team work and two was communication skills, or something like that, and fifteen - probably they tippexed it in afterwards - was technical knowledge."*
>
> *(F39)*

Such an awareness of the demand for general skills reflects the concerns of professional science organisations and students, as well as employers.

2.3 Undergraduate research projects can benefit departments

In addition to providing the student with an important learning experience, undergraduate research projects can benefit departments in a variety of other ways. The recognition of these benefits may to some extent offset the time and expense which departments expend in running undergraduate research projects.

One benefit mentioned by supervisors in the interviews was is in terms of the department's ability to assess the student when it comes to writing references. Undergraduate research projects allow the supervisor to get to know the student over an extended period of time, and to see how they react to a huge variety of learning tasks. Such an interaction gives the following supervisor the confidence to write an accurate and positive reference:

> *"...when I saw her last week, she hadn't as yet decided on what she wants to do when she's graduated. I think she knows what it involves now and she has shown she can do it, so I would have no*

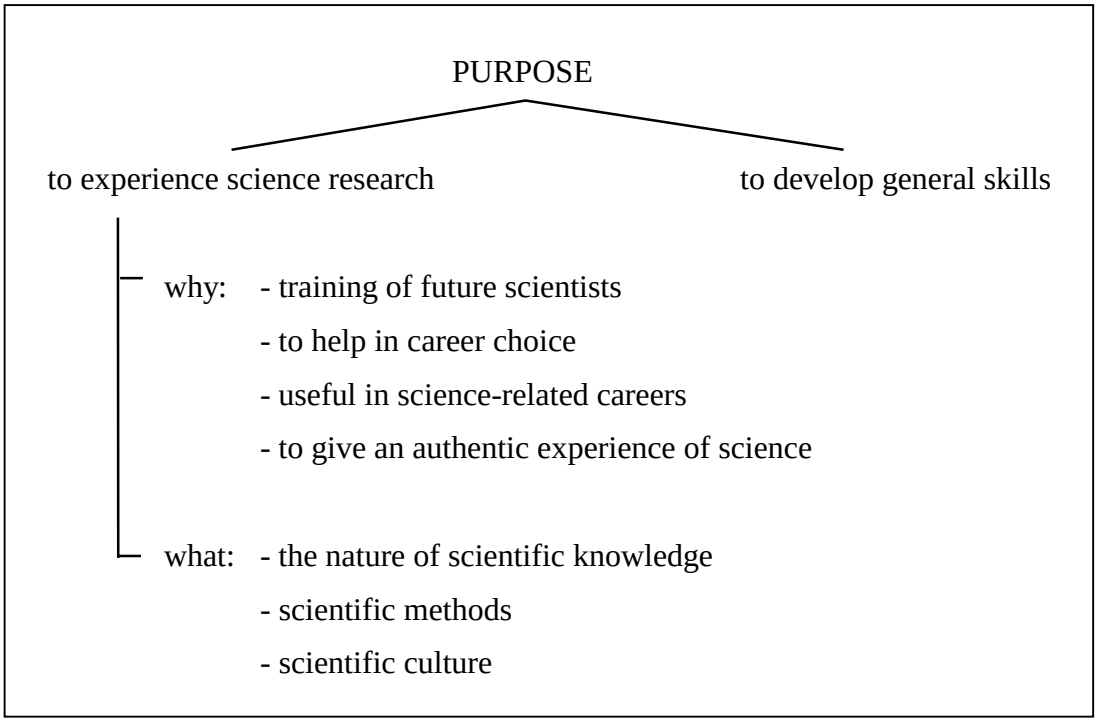
qualms about now writing letters of recommendation for research posts, post-doc, post-grad positions."

(K20)

Although not mentioned in the interviews project work may give many other potential benefits for departments. Many undergraduate projects contribute positively to departmental research programmes. Even though only a few projects will lead directly to publication, many more will yield results which clarify the future direction of research. Furthermore students can often provide an alternative perspective on a research area. In asking unusual questions which may not seem important to experienced practitioners a new line of work or way of thinking may emerge. At the very least, questioning students provide postgraduate students within the group with the opportunity to develop their own thinking, their powers of communication and their supervisory abilities. In this way undergraduate research projects can often provide a significant source of professional development for the *postgraduate* student. It would be naive to suggest that all projects yield such benefits, but supervisors (and undergraduates) do value such interactions when they occur. Indeed many students find work within a research group sufficiently rewarding for them to enrol in a PhD programme.

2.4 Discussion

The diagram below summarises our discussion of the supervisors' responses to the question of the purpose of undergraduate research projects.



By far the most prevalent view amongst supervisors is that research projects should provide students with an experience of science research in action. We

have identified four distinct reasons which are given to justify this view. It is significant that three of these justifications relate to students who may not enter a career as a professional research scientist. Discussion with lecturers during ULISP workshop sessions has raised the possibility of limiting research projects to those students who wish to become research scientists, mainly due to the financial cost to departments of giving all students research projects. The responses from our sample of supervisors seem to imply that such a restriction would be inappropriate.

At the beginning of this section we asked whether or not other teaching contexts could be used to replace research projects in the undergraduate curriculum. We can now address this question by examining what it is that supervisors feel that students learn from projects. In section 2.1.2 we characterised these responses in terms of the contents, methods and culture of science. These three aspects have been used to discuss science issues in a variety of contexts (see Working Paper 1). Which parts of these aspects could be communicated in lectures, practical classes or tutorials, and which can only be acquired through an extended research project?

The idea that scientific knowledge 'reflects consensus of the best work in the field' rather than 'some absolute or philosophical concepts' could conceivably be tackled in tutorial sessions devoted to the nature of modelling in science. We have attended tutorials in the Earth Sciences department at the University of Leeds which show how a single physical system can be modelled in a variety of ways depending on the requirements or interests of the scientists involved. Furthermore the historical progression of disciplinary knowledge which students can experience through lecture courses is a more general introduction to the provisional nature of scientific knowledge. It seems that a development of the students' images of scientific knowledge is certainly not restricted to their work during research projects.

Supervisors mentioned two aspects of the methods of science which students acquire through research project work - an understanding of the 'whole mechanism of research' and the 'witchcraft element' of being able to make laboratory techniques work. It seems unlikely that the students' awareness of the first issue could be enhanced by anything other than research work. It may be that aspects of the 'witchcraft element' needed to get instruments and techniques to work effectively could be appreciated through laboratory practical work. However, conventional practical laboratory sessions tend to provide students with narrowly defined activities in which the preparing of samples and solutions, calibration of instruments and fault-finding has already been done. In practice it is often these auxiliary practices which require the 'tricks of the trade', particularly when instrumentation and procedures are being pushed to their limit in order to obtain original research data. Similarly the realities of the scientific research culture - '95% routine' - can only be appreciated by students if they become involved in their own piece of mini-research.

Many of the supervisors were also aware that research projects enable the student to acquire a wide variety of general skills. Supervisors often referred to these as 'transferable skills' - a term which emphasises that these are capabilities learnt in one context that can usefully be reapplied in other contexts. Such transferable skills are highly valued by employers. 'Showing capacity to improvise' is one example of such a skill (taken from *Improving the Personal Skills of Graduates* - a report from the University of Sheffield 1991). The ability to improvise is of value to research scientists, managers, teachers, lawyers and many other professions. In this sense 'showing capacity to improvise' is certainly a skill with a general applicability. However, the *details* of being able to improvise as a scientist or a lawyer or a manager are very different. Improvisation draws upon a wide range of subject knowledge, cultural knowledge and experience all of which is unique to each profession. It is this context dependence which limits the transferability of such skills.

The concept of transferable skills means that they can be practised by students in a variety of contexts. Departments need not go to the expense of setting up research projects to cover these skills. However given that the specifically science based skills discussed above are valued and research projects are made available to students, it is entirely appropriate that departments endeavour to use the project as a context in which to introduce more generally applicable skills. Whilst the main aim of research projects may not be to introduce general skills, students will have the opportunity to develop such skills during their research project. Student learning in this area could be enhanced if students and supervisors were explicitly aware of the general skills which can be developed through individual projects. These could be included as *educational* aims for the project (see below).

The discussion in section 2.1.2 concerning **what** students can hope to learn from undergraduate research projects may provide the basis for a description of the *educational* aims of research projects. Such educational aims are distinct from the *scientific* aims of individual research projects. A description of these educational aims could well be useful in ensuring that all projects cover these essential requirements. Preliminary evidence arising from the 12 cases used in this study implies that many projects are very tightly focused. Whilst a narrow scientific focus can be justified, many projects do not appear to cover the wide range of educational aims described in this section. Furthermore, it may be that students and supervisors will benefit from an explicit understanding of the scientific and educational aims of individual projects. Whilst many departments include a description of educational aims for projects in general (e.g. in the Project Booklet given too students) this is not the same as making the educational aims of *individual* projects explicit.

3 What type of work is suitable for an undergraduate research project?

Clearly, before answering this question it is necessary to specify the purpose of the research project in the undergraduate curriculum. Section 2 shows that whilst supervisors show a variety of views there is general agreement that undergraduate projects should at least 'enable the student to gain an experience of real scientific work'. This is reflected in the supervisors' descriptions of project work that is suitable for undergraduates.

3.1 The students should be able to get some results quickly

Many of the supervisors are fully aware that one of the student's major worries is that they will not get any 'results' on their project:

> *"Well I like to try and find something that I think they will get at least a result from...they have a limited period of time and I think they panic about not getting a result (...) .I think that an impression that they get, is that they are going to do badly because their project failed. Therefore one of the things I'm trying to look for is something that at least I can convince them at the end of it that they have got a result out of it."*
> *(C3)*

However, since these projects are to some extent open-ended is it possible to ensure that the student will get results? Supervisors have clearly developed an understanding of the sorts of projects to avoid:

> *"Of course, there are always things that crop up in projects that might prevent them from getting results. You tend to avoid one shot projects, with a big build up and either results or no results. You look for things where the student will actually get some feedback along the way and at least get some results, if not as far as one might have hoped."*
>
> *(K4)*

Rather than 'one shot projects' there should be some structure:

> *"Now its very difficult to set a project and say you are going to get the answer to that problem, but if it's structured so that along the way they can get answers (...) they will be able to achieve something and its not all hinging on the last day's work..."*
> *(D4)*

Furthermore it is advantageous to choose projects that become progressively more demanding so that the student is able to get results early on but is still challenged and drawn into the project as it progresses:

> *"One obvious and very important criteria is that there should be some possibility that the student can achieve some measure of success. That may seem absolutely obvious but in our experience I think we are almost always over optimistic. It is therefore highly desirable to have a project which isn't an all or nothing affair, but in which the student can achieve a limited success relatively straightforwardly and then gradually attempt more and more difficult procedures."*
> *(J4)*

These are useful guidelines to follow to avoid the 'no results' outcome which students dread.

3.2 Does it have to be 'real' research?

Many supervisors feel very strongly that undergraduates should be provided with 'real' research projects:

> *"...in order to be interesting it's got to be something that nobody has done before, you can't give them something that you know is guaranteed to work."*
> *(K4)*

> *"I think it has to be a real problem (...) otherwise, they see it as an exercise - they see it as another session of the practical classes and it doesn't achieve the objective."*
> *(P4)*

> *"Its not absolutely necessary but I think its an important incentive to the student to think that they are actually doing something new [...] they make a better effort and the end project is much better."*
> *(L11)*

However the discussion in the last section showed that 'real' research projects have the disadvantage that the students may not get results. Interestingly the following supervisor lays more emphasis on the <u>environment</u> in which the student's project is undertaken:

> *"I think its important [that] they actually get into contact with some of the people who are doing that type of thing,*

> *day in and day out. There are moves because of lack of space to try and think about putting project students into a project student lab. I think that's a bad idea. I think they need to be exposed to the research students and the postdocs, and gain an experience from them as well as just doing the work."*
> *(C2)*

This raises the possibility that a project student working amongst active researchers could gain an authentic experience whether or not their own project is 'real' research. However whilst this may be possible for some supervisors, many will be unable to provide such an environment due to the nature of their research work.

The following supervisor feels that there are a variety of project types which count as 'real' research:

> *"All of my projects are real pieces of research but they're either very speculative, in which case they'll always get some data but it may not be the data we want, or they're bread and butter..."*
> *(E2)*

In this supervisor's research programme there are a variety of research activities taking place. Some of this work is speculative and risky, whilst some of it is fairly routine. However all of these activities have an important role in the research activity of the laboratory and would enable an undergraduate to feel involved in 'real' research.

3.3 Adapting the project to the student

Many of the supervisors felt that certain projects were more suitable for particular types of students:

> *"...you shouldn't put a first class student on a project which is very simple and very mundane where there are no avenues to show brilliance...but on the other hand some students are not that interested or they just cannot cope, and I think it's unfair to put them into a very complex area or a very complex problem - a project with too many outlets - because they completely flounder. Now, I'm against that...a little bit because I feel that all projects should be the same and the students should have a plane playing field to choose which project they like...However in reality I agree - better students have more threads, poorer students have a fairly straight road to go down."*
>
> *(G6)*

There may be ways of matching students to suitable projects at the allocation stage and this will be discussed more fully in the next section. However even after a student has begun a project there is much that can be done:

> *"...when I know who the project student is going to be, we can meet them. I think you can sum up reasonably quickly how competent you think they are going to be, and at that point I can then tailor the project slightly more to the person involved. So if I get somebody who comes in who is obviously struggling and having difficulty I can set the sights lower and say 'Okay, you're going to have problems doing this, why don't you just look at the stability...for example.' Whereas if it was a brilliant student then I would be saying 'Well that's something you'll do on the way to something further away.' So I think there is a tailoring of the project that goes on later."*
> *(C4)*

This indicates that in this supervisor's view a good project has a degree of flexibility built into it. However it is clear from the previous quote that the key to adapting the project to the student is in the supervisor's judgement and monitoring of the student's capabilities and performances.

3.4 Discussion

The supervisors' conceptions of suitable projects for undergraduates show a great deal of variety. In part this may arise from differing views of the purpose of the undergraduate research project (see section 2). Furthermore, distinctions may arise owing to differences in the nature of each subject discipline. Finally, the constraints of cost, time and equipment within departments may have a significant impact on the types of project which are available to undergraduates. All of these factors contribute to the diversity of project experiences available to the student. It is possible to characterise the range of projects across a number of dimensions. Some examples are given below. These are explored in the following paragraphs.

safe (i.e. likely to get data)	⟷	speculative/risky
theoretically based	⟷	practically based
data collection	⟷	working with data already available
within an active research group	⟷	in relative isolation
fixed structure	⟷	flexible/adaptable
teaching project	⟷	real research project

The safe-risky dimension refers to the likelihood that the project will yield results. Projects using a standard piece of equipment which is known to be reliable will almost certainly give results quickly. On the other hand, projects which require special samples prepared from sensitive materials may never yield results if the delicate process of sample preparation is unsuccessful. For the student getting no results is a major worry - particularly when they come to writing their final project report (working paper 4). It is notoriously difficult to predict how successful a proposed project will be. However, given the extensive experience of projects which many supervisors have it should be possible to give a rough estimate of how safe/risky a proposed project is.

The second dimension makes a distinction between those projects which have a strong theoretical component and those which are more practically based. Whilst almost all non-laboratory projects will be strongly theoretical (e.g. computer analysis of experimental data using theoretical models) many laboratory projects will also involve a substantial amount of theoretical understanding. Hence, classifying projects using the theoretical-practical dimension is more than simply saying whether the project involves practical work - it will give the student an indication of the amount of theoretical understanding which they will have to develop during the project.

The third dimension in the table gives an indication of the amount of data gathering which the project will involve. Data gathering includes getting results from experiments (in the laboratory or through fieldwork) and compiling data sets from published databases. In contrast many projects involve the use of data sets which have already been compiled. This is a significant distinction. Many students will prefer the security of an established data set, whilst others prefer to ‘start from scratch’ and gather their own data.

The working environment of the project is a significant factor for students. Many will strongly prefer to work on an independent project in relative isolation, whilst others will prefer to work within the social setting of a large group. Furthermore students contemplating a career in experimental research will certainly benefit from working within an active research group where they can see what PhD research students ‘really’ do, and learn the extent to which modern research often involves the collective efforts of many researchers.

Projects can also be classified by the degree of flexibility built in to them. Many projects are very tightly structured with little likelihood of alternative strategies being followed should results not be forthcoming. For instance a project which aims to establish a particular DNA sequence is wholly reliant on the successful isolation and purification of these DNA fragments. On the other hand many projects are very open ended and can be adapted according to the interests of the student or the successes/failures encountered. For instance an open investigation into the electrical resistivities of metals at low temperatures allows the student to work with a wide variety of metallic samples and temperature ranges.

The final dimension draws a distinction between a 'teaching project' and a 'real research project'. Many supervisors talked about 'real' research in their interview. However, professional research involves an astonishing variety of activities - reading/writing research papers, presenting seminars, compiling literature reviews, making grant proposals, working with technical staff on the design of new experimental apparatus, using computer software to present or analyse data, performing experiments in the laboratory, modelling data, developing theoretical frameworks to explain phenomena, generating hypotheses and designing experiments to test them, or searching for faults in instrumentation. Clearly no undergraduate project can hope to cover all, or even most, of these activities. In using the term 'real research' supervisors appear to be focusing on the nature of the research question - if it has not already been satisfactorily investigated then the project will be 'real research'. In this sense a real research project may introduce the student to only a small fraction of the activities which a professional researcher could be involved in. Conversely, the term 'teaching project' describes a project which does not attempt to investigate a current scientific research question, but does aim to give the student a wide experience of many of the activities which researchers are involved in. Many students will prefer the excitement and uncertainty of a 'real' research project, whilst others will be attracted to the breadth of experience which can be included in a teaching project. The variety of activities associated with a project could be made explicit to students (perhaps using the educational and scientific aims discussed in section 2.4).

The six project 'dimensions' discussed above are neither independent or exhaustive. However, taken together, they do provide a characterisation of the wide variety of project types on offer to students. Supervisors can use these dimensions to ask themselves questions of potential projects - is it too risky, does it require very independent and self-motivated work, could the project be adapted in the event of difficulties? Furthermore, by making these dimensions explicit to students they can be encouraged to choose projects which suit their needs (see section 4.3).

Despite this diversity some issues seem to be relevant to all project types. A particularly strong issue is the students' concern about 'getting results'. In talking with students and supervisors it is clear that each have a differing idea of what a 'result' is. At the outset the students tend to view their project in binary form - 'a question has been posed and an answer must be found', 'in a project you either get an answer or you don't'. However supervisors are more aware of the graduations in between. A 'result' can be a data set, a surprising finding, success with a practical technique, or even a new question! Furthermore results can be positive or negative with respect to a theoretical idea. There can even be 'null' results where the absence of an experimental phenomenon contributes to scientific understanding. Projects which achieve an answer to the original research question are relatively uncommon. This is particularly true of undergraduate projects which occur over a very short time scale. The varied and unpredictable nature of project results causes difficulties when projects are being assessed. This issue of equitable assessment is addressed in section 6.

This distinction between the supervisors' and the students' conceptions of 'result' appears to reflect their differing images regarding the nature of scientific knowledge. Indeed the development of the student's image of scientific knowledge - the forms it can take and their relative status - was stated as one of the intended outcomes of undergraduate research projects in section 2.1.2 under the heading 'Scientific Knowledge'. This important issue is explored in working paper 5 of this series which discusses students' views about scientific knowledge and the actual practice of science. We can now see that the early development of the student's idea of a result could have the dual role of diffusing their dread of 'getting no results' and developing their image of how scientific knowledge appears in the research process. In this way it could be said that a key outcome of the student's work on a project is for them to discover what a 'result' can really be.

The issue of whether undergraduate research projects need to be real research is the second common theme. The concept of 'real' research was explored earlier in this discussion. Whilst many supervisors feel that real research is essential others believe that undergraduates can benefit from projects that are 'research-like'. This may reflect the difference in emphasis between those who see the projects as a training for a future career in research and those who see them as an opportunity to develop their independence and general organisation in the context of a science project. The resolution of this issue may be to recognise this diversity in projects and make it explicit to students. This could be done by characterising potential projects across the dimensions discussed earlier. In this way students could make an informed choice as to whether the nature of the research question in their project is important to them.

A further question arising from discussions with supervisors is <u>how</u> students come to learn about scientific research through doing an undergraduate project. Is experience of research a sufficient condition for students to learn about real scientific research? Can we be sure that a student's interpretation of their limited experience of scientific research will give them an accurate view of what research is all about? In the introduction to this paper (and more exhaustively in working paper 1) we introduce the idea of research projects as an apprenticeship into the culture of science. In this view students are apprentices who are being introduced to the 'tools' of science by experienced scientists. A key aspect of this 'enculturation' view is that the working environment of the student is crucial to their successful apprenticeship. This emphasis on the setting of the project is in addition to the more common emphasis on the projects scientific aim. A further aspect to this view is that it is important to identify the 'tools of the trade' in order to successfully introduce them to the student. Working paper 1 gives an account of the range of 'tools' to which the student needs to be introduced. For example the ability to evaluate competing theories, an understanding of the operation of a research group, the ability to pick out the key facts in a scientific paper - all of these can be considered as the conceptual 'tools' of a scientist.

In addition to the student's undergraduate research project other teaching contexts can also be important in giving the student an authentic image of the activities of a scientist. There may be a role for support materials or support

tutorials where groups of students can reflect on their experiences with a research scientist. During these sessions students could learn from other students and see how their experience is only part of what real scientific research is all about. Experience of group tutorials with final year project students in the physics department at the University of Leeds has shown that these can be very beneficial to students - particularly those whose project work is performed in isolation (this study is part of a DFEE-funded physics disciplinary network involving the universities of York, Sheffield and Leeds).

The third 'common theme' identified in this section was the extent to which projects can be matched to the student. Clearly this is a desirable goal and one which is critically dependant on the successful allocation of projects to students, and the monitoring of student progress through the project by supervision. These two aspects are further explored in the next two sections.

4 Allocating projects to students

In this section we will describe how projects are allocated to students in the four science departments participating in the study. This will enable the different approaches to allocation to be compared. The reflections of supervisors on the effectiveness of allocation procedures in general will then be examined. Suggestions for future development of allocation methods will also be explored.

4.1 Project allocation methods used by departments

4.1.1 Chemistry

Members of staff are asked to submit approximately four projects suitable for undergraduate work. These are then compiled by the Module Co-ordinator into a Project Booklet listing all of the projects available together with a short description of each project. There were 120 projects available for 80 students in the academic year 1994/5 (of which 16 were literature projects - involving library based project work). This booklet is given to students in May/June. Students are asked to return a list of four projects in order of preference. The Module Co-ordinator then collates these lists and allocates projects to students over the Summer break. Students and supervisors are told of the allocations in September/October. The project begins in October. In future years the department intends to move the allocation procedure forward to enable students and supervisors to be aware of their allocation before the end of the Summer term. This will give the supervisor the opportunity to tailor the project to the particular student over the Summer break.

4.1.2 Biochemistry & Molecular Biology

Members of staff are asked to submit up to five projects. These are then compiled by the Module Co-ordinator into a Project Booklet listing all of the projects available together with a description of each project. There were 108 projects available for 86 students in 1994/95. Of these 20% were library projects and 16% computer based projects. This booklet is given to students after the Easter break. Students are asked to return a list of at least 5 projects in order of preference. They have the opportunity to visit prospective supervisors to discuss particular projects before making their choices. The Module Co-ordinator then collates the lists and allocates projects to students. Students and supervisors are told of the allocations in October when project work begins. Students with good second year marks were more likely to get their first choice project.

4.1.3 Genetics

Each member of staff is asked to submit 4 to 5 projects. These are then compiled by the Module Co-ordinator into a Project Booklet listing all of the projects available together with a description of each project. There were approximately 60 projects available for 45 students in 1994/95. This booklet is given to students after the Easter break. Students are encouraged to visit supervisors to discuss

particular projects before making their choices but this is not compulsory. Students then return a list of three *supervisors* together with a preference for a project with each supervisor. The Module Co-ordinator then collates these lists and allocates projects to students. The supervisor may be given the choice of which students they wish to work with if their projects prove popular. Students and supervisors are told of the allocations towards the end of their second year. Students are encouraged to read and prepare for their project over the Summer. Project work begins in October.

4.1.4 Earth Sciences

Geophysical Science Projects

Each member of staff is asked to submit 2 projects. These are then compiled by the Module Co-ordinator into a Project Booklet listing all of the projects available together with a description of each project on one side of A4. In 1994/95 15 projects were available to 11 students, 5 of which were based on data collected by the students during their field study in Greece. This booklet is given to students after the Easter break. Students are asked to return a list of 2 projects in order of preference. They have the opportunity to visit prospective supervisors to discuss particular projects before making their choices. The Module Co-ordinator then collates the lists and allocates projects to students. Students and supervisors are told of the allocations in May. Two weeks of fieldwork/data collection take place over the Summer break with students beginning project work in October, at the beginning of their final year.

Geological Science Projects

Each member of staff is asked to submit about three projects. Students see the list of projects on offer at the start of Semester 2 in their second year (February). Students must arrange themselves into teams of 4-6 and apply for a 'preferred field area' in which to do their work (e.g. Lleyn Peninsula or the Italian Alps). There were 17 field areas on offer in 1995, with 65 geological science students doing field projects (and one student doing a laboratory-based project). Students are encouraged to discuss their choice with members of staff. They are told which field area they have been allocated before the end of their second year (June). Six week field sessions start in July, with project work continuing in October at the beginning of their final year. Project work must be completed and handed in immediately after the Christmas break.

4.2 Methods used in allocating each student a project of their choice

From the previous section the main differences between departments are the number of students involved and the timing of the procedure before the project starts. All departments require the students to give a number of preferred choices based on the descriptions given in the Project Booklet. This leaves the Module Co-ordinator with the unenviable task of matching students with projects. In the words of one supervisor:

> *"[The Module Co-ordinator] attempts to allocate students to supervisors and tries to satisfy two things that are almost incompatible. Firstly that the students should be given, as near as possible, what they want (...) and secondly to equalise the load among the different members of staff."*
> *(J5)*

It is this process that will be examined in this section.

Inevitably some projects will be oversubscribed by students. This can happen because the supervisor is 'popular', or because the subject of the project is 'hot' (e.g. environmental issues, human genome, chaos, AIDS, cancer, Internet...). Many departments resolve these conflicts by referring to examination results from previous years:

> *"...the decision has been made in past staff meetings that all things being equal, if two students want the same project then the one who's got the highest mark from the last couple of years then they are given the benefit of the doubt because they are the ones most likely to benefit in terms of going on to research work. Usually they get within their first three choices actually."*
> *(E5)*

Do the supervisors have any say on who they will be supervising? The following supervisor feels that there are very good reasons why this is not desirable:

> *"No, I think we've tried to avoid that. I felt that it's wrong to allow some members of staff to select just the bright students - but I think it's been a reasonable expectation of each member of staff over the course of the year to get experience of project students who cover the range of ability and that should be so, and staff should design projects that can be tailored in that way right from the start."*
> *(A8)*

However whilst not necessarily disagreeing with this point some supervisors feel that this lack of involvement can be frustrating:

> *"From my point of view it is very discouraging to spend time talking to students who are obviously very keen to do a project with me but I have no control over whether they will or not, and at the end of the day they don't (...) No, the supervisors, as far as I am aware anyway, have no control over the students who end up in their lab."*
> *(D10)*

In one department supervisors were sometimes asked to choose which students they wanted from a list of those who had put them as first preference. Another example of the involvement of supervisors was given where a supervisor was asked to split a single project to accommodate two students. Clearly balancing these issues is part of the skill of being the departmental Module Co-ordinator.

One way in which the student can help *themselves* to make suitable choices is by visiting supervisors before they complete their list of preferences. Departments do encourage students to do this, though take-up can vary. The following supervisor feels that it is important that the student be aware of how easy or difficult it will be to get data on the project:

> *"...when the student comes in I will tell them:*
>
> *'This is what I call a risky project, would you like to take it up? Interesting, but risky. It may not work'.*
>
> *Or sometimes I'll tell them:*
>
> *'This definitely works but it is terribly boring. So you tell me are you willing to take it? And I promise that even if you don't get positive results, you will get a first or whatever. It will not affect your final examination result, you tell me what you want.'*
>
> *And some people want to take a risky project, some people want to take you know this whole range of projects."*
> *(I2)*

In this example the discussion between the potential supervisor and the student includes the requirements of the *student*.

The Project Booklet is read by all students. This provides a second way in which the student can be encouraged to make suitable choices. Here is one supervisor's description of the contents of the departmental Project Booklet:

> *"We put out a paragraph or so of scientific background plus an outline of what software [they] would be using and what the general breakdown of our marking of it would be. Do we think it is mostly a literature project? How much is the data already there? (...) How much is it processing or whatever? So [they] get about a side of A4 with which to assess each project and they choose essentially."*
> *(F11)*

There is a great deal mentioned in this department's Project Booklet in addition to the important scientific background.

4.3 Discussion

All departments rely heavily on the students' choices when allocating projects. This can be justified in so far as the student is more likely to be motivated to do a project with a supervisor that they can work with and in a subject that they find interesting. However the discussion in section 3 shows that these are only two of the many factors which dictate whether a project will be *suitable* for the student. Other factors include the career intentions of the student, the student's desire for 'real' research, their interest in gaining more general skills and their intellectual ability. Despite the best efforts of the Module Co-ordinator it is highly unlikely that all of these factors could be included when allocating suitable projects to students. Clearly the onus is on the *student* to make suitable choices based on a personal assessment of their own needs and information on what they can expect from each project. Our discussions with supervisors have identified two areas which can be used to provide students with the information they require in order to make rational and informed project choices - visits to potential supervisors and the information about each project given in the departmental project booklet.

Many students visit potential supervisors before making their choices. There is much that can be gained from such visits. In addition to the technical background of the project the student can be shown the environment in which they would be working and perhaps meet some of the other people they could be working with. Our discussions with students show that the nature of the working/social environment is very important to them, though they may not be aware of this when making their choices (see working papers 4 and 6). Furthermore the student can be told how the project relates to the project variables discussed in section 3.4. For instance is it a speculative project which could lead to an important publication, or is it a fairly safe but interesting project? Visiting a supervisor is a powerful method to encourage the student to make suitable choices, especially when the discussion goes beyond the technical issues and includes some of the areas mentioned above. Unfortunately, since not all students visit supervisors it cannot be relied on totally.

In contrast, all students must read the departmental project booklet which gives details of all the projects on offer. Many of the issues raised in relation to supervisor visits also relate to the content of entries in the departmental booklet. Is it a speculative or a 'safe' project? Would it be suitable for those going on to research or those entering trainee management positions? Does it require occasional work at weekends or late evenings? Does it involve important but potentially problematic experimental techniques? Will it involve working within an active research group? Will there be numerous opportunities to develop presentation skills and communication skills? Could it lead to a publication? Such issues are discussed in section 3.4 in terms of 'dimensions' which could be used to characterise project types. Clearly such factors are important to students and will help them to make an informed series of suitable choices based on their own requirements of project work.

Once the student has made their list of choices the Module Manager must then match students to projects. In the event that more than one student has put a single project as their first priority many departments give this project to the student with the highest second year mark. This is a clear and manageable method of assigning projects in these contested situations. However in terms of ensuring that students are assigned a suitable project Module Managers could consider whether or not the student has visited the supervisor. Whilst it may not be appropriate to ask the supervisor which student they want, the supervisor could be asked whether any students had visited them and what were their impressions of these students. Unfortunately given the numbers involved such a process may be too time consuming to follow in larger departments.

Ultimately the generation of suitable list of preferences requires input from both the supervisor and the student. The supervisor must skilfully assess their proposed projects in terms of what they can offer students. On the other hand the student must be willing to appraise their own requirements and take the time to read the project booklet carefully and visit the supervisors to discuss potential projects in more detail (working papers 4 and 6 include a detailed analysis of the students' experiences of the allocation process).

5 The supervision of projects

The supervisor has many roles in the management of final year projects in departments. Supervisors must set potential projects, meet students during the allocation procedure, supervise the students during the project and assess projects. In this section we will concentrate on the supervisors' views concerning perhaps the most crucial of their roles - the continuous supervision of students during their final year project. Most of the comments from supervisors are in response to questions C1, C2 and C4 shown below (the full interview schedule is given in Appendix 3).

C1 How have you supervised this project?
C2 How has the student reacted to this supervision?
C4 What do you feel were the successes and failures of the project in terms of its supervision?

In addition responses arising from other questions in the interview schedule have also been included (particularly questions B1 and B4 concerning the student's strengths and weaknesses and their 'broader view' of the project).

5.1 Settling the student in

The first few weeks of project work is a crucial time for the student. Projects follow an open-ended work pattern of which most students have little previous experience. Project work is often undertaken in an equally unfamiliar working environment. This is particularly the case for students who are working within an active research group. Furthermore the subject matter of the project is likely to be unfamiliar to the student. Thus in their first weeks of project work the student must cope with a work pattern, working environment and subject area with which they are very unfamiliar. As the following supervisor is aware, this can be a daunting prospect for students:

> *"We focus on it so much as an individual project that's really their bit of work [...] it's the biggest thing they're going to do and it's scare them. It actually scares them. And [one student] said that he felt completely overwhelmed and totally daunted by this prospect."*
> *(M90)*

Despite this many students find settling in to project work a relatively straightforward process. However some students have a difficult first few weeks, with many never really getting settled into the project (refer to Working Papers 4 and 6). In this section we describe how supervisors see their role in settling the student in.

Most departments use the first few weeks to get the student familiar with the subject matter. Students are given reading lists and asked to prepare a proposal

for the project. Here is how one department describes the purpose of the proposal in its 'Information for Students' handout.

> *For the first four weeks of the year you will not enter the laboratory. Instead we require you to write a research proposal. This comprises:*
>
> *i) a review of the background literature*
> *ii) a statement of the objectives of your project in relation to the present state of knowledge*
> *iii) an outline of the experimental approach you propose to undertake to achieve the objectives, indicating the anticipated milestones you expect to pass in pursuit of these objectives*

The overall aim of the first few weeks is described by the following supervisor.

> *"Get them involved. Get them to feel that it's their project as soon as possible"*
>
> *(P101)*

One supervisor felt that introducing the student to the other people in the laboratory around whom they would be working was also an important part of settling the student in.

> *"They have no problem whatsoever [getting settled in]. Even if you are a physicist who wants to come and work in my lab, you will be made quite at home. That's my speciality, I'm very proud about that (...) we sit together, the first day when they come and I'll (...) introduce everybody not [just] my lab group but others who are working (...) with something else."*
> *(I16)*

The supervisors' views of their role in the 'social' integration of the student will be further explored in section 5.5.

5.2 The role of PhD students and other researchers

Seven of the twelve supervisors interviewed required their students to work alongside PhD students and post-doctoral researchers. Supervisors feel that these researchers have a key role to play in the supervision of undergraduate project students.

> *"Really, it's sort of an intermediate role between me and the [project] student. I don't have enough time to be able to stand with a project student all the time and say well this is how you pick up the pipette and this is how you use it. (...)*

> *that's really what the research students and postdocs are doing, they're [saying] 'this is where the balance is but for example you may have to weigh out small amounts, this balance isn't good for that'. So, its really the practical details plus some of the background information about what else is going on in the lab. (...)*
> *I think the other thing that it's important for is to give the [project] student somebody to moan to. I mean it's not always the case (...) but there will be cases (...) where the student doesn't get on with the supervisor very well. I think having those other people around at least gives the student a chance to moan about what he's been told to do to somebody else who can be sort of sympathetic."*
> *(C27)*

The following supervisor feels that PhD students and post-doctoral researchers could gain from becoming involved in supervision in terms of their professional development.

> *"I would hope the first point of call by the research student would be to the post-doctoral fellow. A lot of the minor problems, difficulties in interpreting results - that sort of thing, would be done at that level, which provides the post-doctoral fellow with an opportunity to do a bit of supervision like that."*
> *(D41)*

All of the seven supervisors whose students worked amongst PhD students and post-doctoral researchers valued their contribution to the supervision of undergraduate students. However the following supervisor sounds a note of caution.

> *"...the thing that I think one has to be very sensitive to is the possibility of mis-communication between the student and the people in the lab. Now this can happen for a great variety of reasons, but (...) my research students (...) often don't realise how difficult it is for somebody who is starting to understand what they are being told (...) particularly because, regrettably, a lot of our undergraduates don't seem to realise the necessity to write things down and they seem to trust to memory. I find that you have to mediate, you have to just check after somebody has been told something that they have actually understood the message (...) So one has to be very aware of what is going on."*
> *(J24)*

Since we did not interview any PhD students or post-doctoral researchers it is unclear to what extent they value the opportunity to become involved in the

supervision of undergraduates and are clear about their role in the supervision process.

5.3 Giving the student guidance and independence

All of the supervisors are clearly aware that there is a delicate balance to be struck between ensuring that the student has sufficient guidance to prevent them from floundering, whilst at the same time giving the student opportunities to demonstrate independent thought. Discussions with students show that the nature of this balance can often be a source of frustration for them (refer to working papers 4 and 6). The following supervisor is fully aware of this issue:

> *"Personally I have a tendency which I have been curtailing with time of being more prescriptive than I should be. Telling a student what to do rather than putting it in terms of questions and asking the student what to do."*
> *(G55)*

Being too prescriptive can be counterproductive, particularly for the more able students:

> *"I tended to leave her to do things on her own a reasonable amount. I thought she was capable of that and sometimes I think the good students hate it if your always looking over their shoulder because they feel then that they're being tested at every stage and that they're not getting any independence at all. So, with a good student (...) I tend to stay back a little..."*
> *(C32)*

Some supervisors felt that by being too prescriptive the students lose the opportunity to develop a sense of ownership towards their project:

> *"There are certainly quite different views about how we should supervise, and some people think if we over supervise then we're imprinting too much of our own ideas on the students and taking it away from the students."*
>
> *(M98)*

The following supervisor feels that allowing the student to 'fail' is an important learning experience for them. Indeed authentic research work often involves a series of 'failures' each of which provide information leading the researcher to a successful finding.

> *"If we're in a situation where there are four approaches (a) - (d) and I would normally choose (a) and they would choose (d) I would ask them to think about it and if they still want to do it I'll let them do it because I think there is some*

> *value, not in outright failure, but failure in the way that you can see why you've failed. It would also depend on the time in the project, I would much rather the students did that in the first few weeks than when they're in the final stages (...)"*
> *(E32)*

However another supervisor pointed out that allowing students to make their own choices about project direction needs to be done with due regard to the possible safety implications and within financial and resourcing limits.

The idea that the degree of guidance/independence given to the students should depend on the stage that the student is at on their project was a recurring feature of the supervisors' responses.

> *"It's always the case with anybody that you have to spend a bit more time with them initially than later on, because they basically they don't know anything about what they're trying to do when they first come in to the lab. So I think that one thing is trying to get them started you spend more time with them and then leave them more as they get further through."*
> *(C38)*

The following supervisor feels that whilst students should be given independence there are some aspects of research work which require guidance from an experienced practitioner.

> *"I still find I have to provide a large part of the thinking in my group - I don't think that's an exaggeration - in terms of actually assessing even tactical rather than strategic decisions about where you need to go from here. So my position is usually being presented with data (...) assessing them just to check that the student's interpretation is the same as mine, and then deciding on what the next step might be. Sometimes it's obvious, but there are other times when I feel that my involvement is pretty necessary."*
> *(J22)*

Thus, the supervisor has the ability to see the 'broader picture' and can provide the tactical guidance about the general direction of the project:

> *"Well, my role is as an architect, steering the work forward."*
> *(E35)*

Typically the student is unable to look beyond the technical details of the immediate problem (refer to Working Papers 4 and 6). For them the guidance in terms of strategic direction that the supervisor can provide is invaluable.

5.4 Monitoring the project and the student

Supervisors were very much aware that monitoring the student was an essential part of good supervision:

> *"I think the hard part for the supervisor is to recognise where the student is [...] and to ease them forward and not hit them too hard too early which puts them off."*
> *(L30)*

Perhaps the most common technique was the 'open door policy':

> *"...it's a question of saying to them right from the beginning (...) 'if there's anything you don't understand come and knock on the door and I'll talk to you about it'. So it's that sort of approach. I don't have a very formal way of doing it, I think it's better not to."*
> *(C27)*

There is a strong emphasis on the student being able to ask questions of the supervisor:

> *"I very much feel that [supervision] is an ongoing process and that each week, almost each day, that he's in the lab I would see him, not actually to speak to him in any detail, but I would have been there and I like to think that the students can come and ask me questions whenever they want."*
> *(D38)*

However, the following supervisor is concerned about how difficult it can be to get feedback from some students.

> *"I always give them quite a lot of literature to read ... but I don't think that necessarily helps unless they will come back and discuss it. Often they are reluctant to do that. It's part of not wishing to admit they don't understand I suspect. Often they go away and read the papers and it's quite clear when they come back at the end with a written description of what they've read that they didn't understand, and yet they won't come and discuss it, ask about it you know, in most cases. If they do then that's a big help."*
> *(P19)*

As a result of this many supervisors stated that different students need different styles of monitoring. The following supervisors are aware that some students do not have the tendency or capacity to ask questions about their progress on the project, and that a more pro-active style from the supervisor is required.

> *"In [student X's] case it was almost a question of coming in on occasions and saying (...) "Tell me what's happening, where are you at? Why?" but certainly trying to ask explicitly the questions I felt he ought to be asking himself. With [student Y] (..) it was clear in a sense that she was progressing so I didn't do much more than check she was progressing. With [student X] it wasn't that there were a lot of things coming out that needed understanding, it was just to try to keep him doing things."*
> *(A40)*

> *"I think setting deadlines is quite a good idea because it made the students, it actually did make them do things by certain dates and I think time management is the one thing that really cripples most of them [...] so I did set them strict deadlines"*
>
> *(M74)*

Some supervisors felt that it was up to the student to make the most out of the opportunities presented to them.

> *"I tend to use the same style in all of them. I've found it quite effective in the past and I tend to use it whether or not they're committed students. If they're not committed students I don't feel it's appropriate to bash somebody over the head and push them forward. It's one of these leading a horse to water and not making it drink type of things. I would give them opportunities to get there but life's too short and we're all too busy to push people to get there."*
> *(E36)*

> *"I would have liked to have been able to motivate [the student] more than I did [...] but part of that is you can't go seeking the students round the department and sit them down. You basically have to have some communication which comes from them."*
> *(L49)*

During a ULISP workshop session project supervisors discussed the nature of the discourse between student and supervisor following an activity based on a draft of this working paper:

> *"The supervisor needs an open, tolerant approach - ask students <u>open</u> questions 'What are the most difficult things you have found?' 'What can you do about that', rather than <u>closed</u> questions. Need is to build on what students actually have done - rather than what they ought to have done...The whole issue is critically dependant on overall student/staff relationship in department - and on how*

> *many experiences are shared (genuinely) by staff and students."*
> *(Workshop 5)*

Many of the insights gained during such workshop sessions are included in the discussion sections of these working papers.

A variety of techniques are used to monitor student's work. Supervisors have developed individual styles which seem to work for them. These are almost always informal methods which help to establish a rapport between student and supervisor. In the following section we explore the nature of this relationship between supervisor and student.

5.5 The supervisor-student relationship

The final year undergraduate project gives students a rare opportunity to work closely with a practising scientist. Over the project period of up to 6 months both student and supervisor will get to know each other better. Indeed many supervisors see great value in this developing relationship.

> *"...in general I think away from the project I hope that we also made her feel welcome in the lab. and that she could perhaps come to any of us in the lab with problems that were outside the practical project (...) she actually knew quite well a group of people that she could come to and say 'I don't understand this' so I think that's an important aspect as well."*
> *(C33)*

Supervisors talked at length about the nature and significance of their relationship with project students. Many supervisors are aware that the development of a good working relationship involves an understanding of students' often unrealistic expectations of project work.

I *...student's keep feeling that they've got to enlarge the project to make it worth while (...) whereas supervisors know they've got to narrow the project.*

S *But that's partly because of the media - the way science is appreciated outside that it's seen in terms of great leaps forward (...) Darwin sitting down and writing the origin of species as if there was no accumulation of small pieces of information that made that bit in science possible. That's something which most of the students don't appreciate (...) I can look back to my own undergraduate project and that was where I started to learn about being over ambitious because I made exactly that mistake.*

(P96)

Over ambitious expectations can cause the student to feel unnecessarily down-hearted:

> *"She, like many students (...) found the effect of disappointment rather greater than she had anticipated. I mean students often aren't prepared for (...) how depressing it can be when you find that you're getting problems. She was well able to overcome this. Again that has been quite a useful lesson."*
> *(J11)*

In addition to a consideration of the student's expectations the following supervisors are aware that **their** expectations of the student must also be realistic, particularly given the students' other commitments.

> *"I think there is a grave danger, particularly within the modular system, that there's a fairly careful accounting for students' time (...) if the project goes well it's very tempting for the student to put in a lot more [time] and it's very easy for an unsympathetic supervisor to demand more and whilst (...) it can extend people beyond what anyone thought they were capable of and not damage their other 90 credits worth of examinable material, I think that's the unusual case rather than the rule."*
> *(A47)*

> *"They are final year undergraduates they are not postgraduate students, they are not post-doctoral fellows, and so I can't just sort of present them with a problem and say - right off you go and find an answer, or find a way of getting to that answer. We have got to be able to direct them towards it..."*
> *(D19)*

Thus, a successful supervisor-student relationship will only arise where both the student and the supervisor have realistic expectations of the project.

In the day-to-day running of the project the following supervisors stressed the value of motivating the student.

> *"Sometimes the student seems fairly mediocre until he or she gets really into a project and suddenly they see that this is good stuff you know, and it's worth doing. Often contact with individuals, with individual members of staff will sometimes [do this]. Re-addressing my own experience, it was contact with particular individuals as an undergraduate which enthused me about particular areas..."*

(P49)

"...my procedure of giving confidence to the students 'Oh yeah, you can do that, come on, you can do that. If it goes, we'll do it a second time.' That sort of thing, I always like to boost their ego, and their confidence. It works very often..."

(I15)

In one department each student worked as part of a small group for part of their project. Supervisors felt that such peer group work could be a major source of motivation, particularly for students who may have struggled on their own:

"I was quite impressed as a whole by the group [...] and that the two people that I thought were poorly motivated actually produced quite good reports [...] I was really pleased with their marks."

(M58)

"...hopefully they do have group discussions on how they're working each day and they talk about it and they give each other support and they also motivate each other."
(M65)

"I think its useful to have group sessions right the way through [...] they can see what some of the others in the group have been doing and that then helps them go off with an idea of what they might do if they made that little bit extra effort.."
(L36)

Supervisors feel that realistic expectations and a motivating environment are important if the project is to benefit from an effective and stimulating supervisor-student relationship. The final two quotes show how both students and supervisors can benefit from such a relationship.

"One of the other students who was on the project (...) I don't think I've ever seen him smile in the two years he was here previously. I'd never really heard him do anything more than grunt if you really worked on him. By the end he was smiling, talking, getting quite cheeky and it was all very good, the confidence and the interest that developed in him, to the point he couldn't be bothered to conceal he was interested any more. He worked incredibly hard (...) a really genuine interest developed, which may be more important than the science detail that was uncovered."
(A52)

> *"If we got the data and the right research projects bubbling along you can use them and you can almost sound like a little temporary research group and it's delightful. Certainly when we were dealing with [a subject area] a few years ago the student society (...) dragged in me and the four I was supervising and they (...) got us all to give a seminar at the end of the year on what we'd got out of it. I mean that's an extreme example but it was absolutely delightful. When it works it's marvellous. So yes it can go really well."*
>
> *(F95)*

5.6 Discussion

In section 5.1 we identified three aspects of project work with which the student is unfamiliar. Most of the supervisors' comments referred to the first of these - becoming familiar with the subject area of the project through background reading and the preparation of a 'proposal' for the project. Fewer supervisors mentioned the importance of introducing the student to the work pattern of project study. It may be that the first meeting with the student should set the 'ground rules' for how they are expected to work. These could include a maximum and minimum number of hours per week on the project or the requirement to use their own initiative and question the direction in which their project is going. This first meeting could also make it clear to undergraduate students what role the PhD students and postdoctoral researchers in the laboratory (if any) have in their supervision. Finally, how can supervisors help the student settle in to the working environment of their project? If the project takes place in an active research laboratory is the student introduced to other students, researchers and technical staff working in that area? Is the student made aware of the variety of resources available to them? (e.g. computer terminals, research group libraries, stores facilities.) Since the nature of projects varies between departments each department could draw up a list of issues which the supervisor should discuss with incoming students in their first few weeks of project work.

As stated above it is important that undergraduate students are clear about what role the PhD students and postdoctoral researchers in the laboratory (if any) have in their supervision. The supervisors' comments (and comments made by students - see Working papers 4 and 6) show that their role is very important. As a result there may be value in making the nature of this role explicit to PhD students, postdoctoral researchers and technical support staff. Whilst many postdoctoral workers and PhD students will have a good conception of what it is like to be a (capable) project student they will have little conception of the complex role of being a project supervisor. Some departments assign a particular research student to each undergraduate student - a method which seems to work well. Staff development courses designed for PhD students and postdoctoral researchers who will be involved in the supervision of undergraduate students

may also be of value. Indeed such training can be seen as part of the professional development of these researchers

We can identify three interrelated elements in the supervisors' responses concerning the balance achieved between the guidance and independence given to students. Firstly, many supervisors stated that they allow their more able students a large degree of independence whilst giving weaker students the close guidance that they need. Secondly, that the degree of independence given to students should depend on what stage their project is at. For instance students at the end of a project which is yet to yield results would be given close guidance, whilst students who achieve 'success' very early on may be allowed a free reign through the remainder of their project. Thirdly, many supervisors stated that whilst most students could be given a degree of independence concerning the day to day activity of their project, the more strategic, long term planning is best done by the project supervisor. This latter view reflects the supervisors' awareness that many undergraduate students have great difficulty in achieving a 'broader view' of their project in terms of its place in the wider research programme of the discipline (this aspect is discussed further in working paper 4).

Supervisors have a variety of ways which they use to monitor a student's work on their project. Most tend to drop the formal requirement for a weekly meeting after the first few weeks and thereafter rely on intermittent contact and approaches from the student. Many discuss the 'three stages of a project'. The first few weeks of settling in is followed by the middle stage of the project where the student is left largely on their own. The intensity of supervision is then picked up as the student approaches the end of their project and begins to plan their project report. Such an approach relies heavily on the students' ability to a) realise what questions they need to ask and b) show the initiative to approach supervisors when they are concerned about any aspect of their work. Whilst most students will be happy to question their supervisor about the technical problems that they encounter, it is less likely that they will discuss their concerns about project direction, personality clashes within the laboratory or increased workload from other module work. It may be that supervisors need to take a more proactive approach with these issues.

The supervisor's success in discussing sensitive issues with their student will depend on the nature of their working relationship. Many supervisors mentioned the importance that they attach to building up a good working atmosphere for their project students. Our discussion of the supervisors' responses concerning this relationship emphasised the need for supervisors to be aware of the expectations that students have of project work - expectations which are often wildly over ambitious. Secondly, supervisors felt that it was important to make reasonable demands of the student - especially given the pressures from other module work. Thirdly, it was clear that many supervisors consciously tried to motivate their students to do well on their project work. These three aspects identified by supervisors could be termed the 'human' side of supervision. An awareness of these issues is likely to be important in fostering a good working relationship between supervisor and student.

However, what happens on the occasions when the relationship between student and supervisor is breaking down? Discussions during ULISP workshops indicate that a key factor here is for the student to have someone else associated with project work with whom they can discuss these issues - a 'project friend'. This could be a sympathetic PhD student or even an undergraduate peer. Furthermore, the issue of student-supervisor relationship is related to the general atmosphere of student-staff within the department as a whole. The extent to which informal interactions occur and are valued *throughout* the course.

In section 2.4 it was suggested that a useful distinction can be made between the *scientific* aims and the *educational* aims of an undergraduate project. For example, an educational aim might be to give the student an understanding of the structure of a science research group, whilst a scientific aim would be to isolate and sequence a DNA fragment. Many of the approaches to supervision mentioned here demonstrate that supervisors are aware of these educational aims in addition to the more scientific aims of the project. One supervisor felt this distinction between the project and the science very clearly:

> *"I've tried to think perhaps almost more about how is the project going as a project rather than how is the science going."*
> *(_49)*

It may be that a fuller description by departments of what the educational aims for project work really are would be of benefit to supervisors and could help students to get the best possible learning experience from their project.

Supervision is a central part of the student experience on a project. Our discussion has focused on the supervisors' views. However the students' experiences of being supervised are also of crucial importance. Working papers 4 and 6 give full details of the students' views.

6 The assessment of projects

Final year undergraduate projects contribute up to 33% of the final year mark in science departments (equivalent to 40 credits from a total of 120 credits in the final year). Given the variety of project types available how can they be assessed fairly and consistently? In this section we will explore these issues by first describing the methods of assessment used by each participating departments and then going on to discuss supervisors' comments on how these methods work in practice.

6.1 Project assessment methods used by departments

6.1.1 Chemistry

Students can choose either a 20 or 30 credit laboratory-based project module. The option of a 10 credit literature-based project is also available. Both of the students followed in this study did the 30 credit project module. The approximate breakdown of assessment methods and the associated weightings is given below.

Chemistry	
Preliminary Report (after 3 weeks)	5%
Performance during the project	35%
Project Report	50%
Oral Presentation	10%

In Physical Chemistry a detailed assessment form is used to structure the supervisor's assessment of their students. This is based on a sheet devised at the University of Edinburgh. Supervisors are asked to give each student a mark in a total of 14 sub-categories arranged over 5 main categories: Initial Report, Review of Literature, Experimental/Practical Work, Project Report and Oral Presentation. For each of these sub-categories a series of descriptors is provided which give an indication of what the student must have achieved to gain a certain number of marks in this sub-category. The maximum number of marks available in each sub-category is suggested on the mark scheme but can be reduced by individual supervisors if it is thought that the sub-category is not very relevant to the particular student project being marked. Such an assessment scheme enables supervisors to adapt the marking scheme to the characteristics of individual projects.

6.1.2 Biochemistry & Molecular Biology

A 40 credit Research/Literature project is taken by most students. A 20 credit project is available for Combined Studies students. The breakdown of assessment methods and weightings is given below.

Biochemistry & Molecular Biology	
Project Report and performance during project	70%
Oral Presentation	10%
Project Viva	10%
Written Comprehension Paper	10%

Supervisors use a standard departmental assessment sheet for assessing the project report and the student's performance on their project. The two hour written comprehension paper requires the students to write a summary of a published paper which they have not seen before, followed by a series of comprehension questions probing their understanding of the paper. Each student is given the same paper to read.

6.1.3 Genetics

The Genetics Research Project is a 40 credit module. A 20 credit project module is available for Combined Studies students. The assessment methods are listed below.

Genetics	
Project report and project viva	50%
Supervisor's assessment of the student's performance during the project Proposal prepared before the project starts Short talk to undergraduate peers and lecturers Poster presentation	50%

The proposal includes a literature search and safety assessment. Students must complete a proposal before they begin work on their project.

6.1.4 Earth Sciences

Geophysical Sciences

The Independent Geophysical Project is a 20 credit module. Assessment is based on a report from the supervisor on the student's performance, a project report and a viva. Each project has its own breakdown of percentages across the areas listed below.

Geophysical Sciences
Statements of aims and background information
Data acquisition, processing and observations
Interpretation, discussion and conclusions
Presentation and style

The percentage given to each of these varies from project to project. The supervisor is asked to give a weighting which reflects the individual nature of the project. The students are made aware of these weightings at the beginning of their project work.

Geological Sciences

The Independent Summer Mapping Project is a 20 credit module. A 10 credit module is also available. Assessment methods are outlined below.

Geological Sciences (suggested breakdown)	
Field notebooks	30%
Field maps	20%
Report	50%

In practice supervisors are required to develop an individual mark scheme for each project based on a standard template.

Projects are marked independently by two markers (neither of whom is the project supervisor). In the event of these two marks showing greater than 8% discrepancy a third person is asked to adjudicate. One lecturer felt that students were able to be more relaxed during supervision sessions because they knew that their supervisor was not directly involved in the project assessment.

6.2 Criteria used in the assessment of projects

The previous section is a descriptive account of assessment *methods and weightings*. In this section we wish to explore the assessment *criteria* used by departments. By criteria we mean the categories for which students are given marks e.g. presentation, initiative and enthusiasm. Many of these criteria appear explicitly on the departmental assessment sheets.

All departments state clearly that ‘results do not matter’ in the assessment process. The following quote is taken from one departments ‘Guide to the Third Year’.

> *"We attempt to assess each project independently, according to its own merits, rather than relative to other projects. This is important to emphasise because not all projects guarantee results - in fact very few projects produce useful results each year. Project assessment, therefore, is based not so much on results obtained, but on performance....A well-presented report of unsuccessful experiments often gets a higher mark than a garbled account of something that works."*

However:

> *"Always we try to emphasise that they're not being marked on how much they've produced but how well they've approached it and how well they've described what they've done and so on. They find that very difficult to believe."*
>
> *(P71)*

One departmental assessor stated that 'the assessment panel will also take into account such factors as there being limited time for experimental work'. However, despite the best efforts of departmental assessors many students still feel that unless they get some results they will not get a good mark.

A factor that clearly is important in the assessment of projects is the amount of effort that the student has put in.

> *"Okay, in my case I have a standard set up in my mind. Is the student diligent enough or not? Is he or she is working hard enough? Are they putting enough hours and serious about their ambitions? (...) Any science or anything you like you're successful only if you work hard."*
> *(I59)*

To incorporate this factor many of the departmental assessment sheets include a section asking for the number of hours that the student spent in the laboratory, or a rating 1 to 5 of the student's enthusiasm for the project.

One department had an innovative way of responding to the diversity of project types. Rather than having a standard assessment sheet for all projects the supervisor is asked to devise an individual mark scheme tailored to each of their projects:

> *"The students are given guidelines on how to do their project and at the bottom of those guidelines there is, for their information, an example marking scheme - presentation, style of report ten percent, literature review fifteen, data processing you know sixty, the answer the rest. [A] project that is very much fieldwork orientated might be like that. But then the summary sheets that we*

> *provide to the course convenor actually have an open space (...) You provide the marker with a list of suggested headings and weightings so there are those for whom presentation and style might be more important. There are projects for which the literature review might be crucial (...) So we are very flexible. We want to respond to individual projects and people's needs."*
>
> *(_77)*

A further issue is the extent to which the student is aware of the assessment methods and criteria. Indeed interviews with the students participating in this study show that many students have little idea of how their project will be assessed, particularly at the beginning of their project. At least one department includes the supervisor assessment sheet in the 'Information for Students' pack. By making the methods and criteria of assessment clear as soon as possible, students are more likely to accept that it is their performance rather than their results which matter most.

Finally what role does project assessment have in the development of the learner? Since all of the formal assessment mechanisms discussed so far have been summative they cannot feed back and influence the student's performance on the project (though clearly *informal* mechanisms of continuous assessment can and do play this role - see section 5.4). However the following supervisor clearly feels that given adequate feedback, the formal assessment procedure can be beneficial in terms of student learning.

> *"I mean, my own personal experience, and admittedly that's a long time ago - what I try and not to do is the lack of feedback from the whole assessment process. People have put a lot of effort into these dissertations, they've put a lot of personal time into them and all that comes out then is a mark (...) I strongly believe that more feedback would be beneficial. I felt bitterly when I did my dissertation that I didn't get any feedback at all, I'd done a lot of effort on it (...) We always want some feedback. I mean just the mark is not really [enough]."*
>
> *(G50-54)*

6.3 Discussion

The assessment methods and weightings used by departments (section 6.1) are broadly similar and are very clearly expressed to students in the departmental project booklets. However the departmental criteria of assessment are not always made clear to students. Furthermore, supervisors in their daily assessment of a student's performance often rely on personal criteria which they have found to be useful. These may or may not reflect the official departmental view. However these personal criteria are instrumental in shaping the relationship between

supervisor and student. The undergraduate student will constantly be receiving feedback from the supervisor on the basis of these personal criteria. Our discussion in section 2 of the purpose of research projects is relevant here. An effective assessment procedure should assess the student's achievements of the aims of the teaching activity. We saw in section 2 that supervisors often have very different conceptions of the aims of research projects. These differences are likely to be reflected in their personal conceptions of the assessment criteria.

All departments have official assessment criteria on the marking sheets which are filled in by project assessors. Following from our discussion above it is clear that these official criteria should reflect the departmental aims for undergraduate research projects. A further issue is how such sheets are used in practice. Even with a very detailed assessment sheet it is always necessary to use personal judgement to assess a student. Such personal judgements are likely to reflect the personal criteria held by each marker. However the type of data collected in this study makes it very difficult to say whether this has a significant impact on the assessment of students. Perhaps the key message is that departmental assessment sheets should include as detailed a marking scheme as is practicable, and that these criteria should be designed to correspond to the departmental aims for project work.

A further issue raised by supervisors is appropriate feed back to students regarding their assessment. We have already mentioned the importance of making it clear to students at the beginning of their project what the assessment criteria are. Following from this it is also important that students are aware of their progress during the project. Given the danger of supervisors relying on personal assessment criteria during informal feedback it may be useful to give students a 'mock assessment interview' in the middle of their project. This would involve the student being talked through the official departmental assessment sheet and shown what mark they would get in each part. This would allow the student to take steps to improve their performance if appropriate.

The assessment of projects is often a source of concern amongst students (working papers 4 and 6). Making the procedure absolutely open to students helps to minimise this concern. Furthermore, ethical assessment requires standardised criteria which relate directly to departmental aims for undergraduate project work.

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 schedule used with supervisors

A The Research Project as part of the undergraduate course

A1) What do research projects contribute to the undergraduate course?
Expected factors: develop general skills, scientific skills, understanding of the research process, understanding of scientific concepts, preparation for future career...

A2) What are the essential requirements of a project for it to be suitable as an undergraduate research project?
- How are projects allocated to students in your department?

A3) How did this particular project come about?
- where did the *idea* come from?
- is it related to other work in the department/field?
- in hindsight how would you evaluate this project in terms of its suitability as an undergraduate research project

B The student's experience on the research project

B1) What strengths/weaknesses did the student show during this project?
- what were the most difficult aspects of this project for the student?
- how did they react to working in an unfamiliar environment?
- how did the student's performance change over the period of the project?

B2) In general what can research projects tell students about the work of a scientist? (cf. question A1)
- do you feel that the student has gained an understanding of what it is like to be a scientist through working on this project?
- what image of a scientist do you have in answering this question?

B3) What are the main findings of this project?
- are these findings important? To whom?
- do you feel that the student has a feeling for the significance of these findings?

B4) We have discussed the extent to which the research project has given the student a sense of being a scientist (B2). We have also discussed the sense that the student has of their scientific findings having a significance in the scientific world (B3). We could describe these as aspects of the student's 'broader view' of their project. What methods have you found are effective in fostering the student's sense of this 'broader view'?

B5) How would you have approached the project if you had been doing it?

- what would you see as characterising good scientific practice for this project?
- What aspects of the student's work would you say were good scientific practice and which were not?
- what have you got that they haven't?
- (*perhaps use an example from the student's project)*

C The role of the supervisor

C1) How have you supervised this project?
- what has been your role as supervisor during this project?
- what factors influenced your supervision style for this student?
- what other approaches have you found effective with other students?

C2) How has the student reacted to this supervision?
- have the students reactions changed over the project period?

C3) What criteria have you used in assessing the performance of the student on this project?
- the write-up/report
- summative assessment of performance over whole period of the project
- are these criteria standardised/written down for your department?

C4) Clearly supervision is a sensitive balance between guidance and independence involving the establishment of a personal relationship with the student. What do you feel were the successes and failures of this project in terms of its supervision?
- *What is your evaluation of your performance as a supervisor on this project?*

C5) What image of 'being a scientist' would you wish the student to have at the end of the project?

D General

D1) Did the project go as you had expected it to?
- did the direction of the project change?
- did it achieve as much as you had expected?
- did your expectations of the student change as the project proceeded?

D2) Roughly how many research project students have you supervised before?
- how many do you do each year?

D3) What issues concerning this research project do you feel we have not covered in this interview?