Undergraduate Learning in Science Project

Working Paper 8

A summary of findings and recommendations arising from the Research Project Study

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Abstract

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

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

This paper presents a summary of research findings from the study. Recommendations arising from these research findings are also presented. These recommendations are intended as suggestions or discussion points, and are aimed at science lecturers who are involved in the implementation of research projects in the undergraduate science curriculum.

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Contents

1 Introduction

Research projects are a key feature of the final year of undergraduate science degrees at the University of Leeds. Science lecturers feel that they provide a unique opportunity for students to experience what scientific research is really like. At the same time lecturers are aware that the students' experiences of project work are extremely varied. Whilst many students find project work stimulating and rewarding, others become overwhelmed, demotivated and stressed. The ULISP study of research projects set out to address this problem. Our main research aim was to identify those features of project work which have an important influence on the students' learning experiences.

Over a period of 18 months lecturers and educational researchers worked together gathering and interpreting data. Regular workshops were held to discuss final year undergraduate project work. Twelve students and their project supervisors were interviewed and visited throughout the duration of project work. Finally, a survey was administered to all supervisors and students in the four participating science departments.

The outcomes of the study have been reported in working papers 2 to 7 (appendix 1). These papers give a detailed analysis of discussions with students and supervisors and include numerous quotes from interviews with students and supervisors.

In this paper we present a summary of findings and recommendations. Each section contains very brief descriptions of key *research findings*. Each of these is followed by a *recommendation* suggesting how departments can act on the research finding to improve the effectiveness of project work. Each finding and associated recommendation is given a separate section number and recommendations appear as italicised statements in boxes. At the end of each section references are made to the sections in working papers 1 to 7 in which more details can be found.

In many cases there may be institutional, financial or time constraints which make some recommendations difficult to incorporate into existing module programmes. The main aim of this paper is therefore to present lecturers with a summary of empirical data about the current practice of research project work in their department. This can then be used, together with their own experiences, to inform their decisions about how to improve the effectiveness of research project work as a learning experience for their students.

2 The aims of project work

2.1 Scientific project aims and educational project aims

In discussion with students and supervisors we identified two important uses of the term 'project aims'. The first usage relates to the specific scientific details of an individual project. An example of such a *scientific aim* would be 'to isolate and sequence the *lacZ*$^+$ gene in *E.coli*' . The second usage can be described as the *educational aims* of project work. An educational aim for the project described above might be 'to enable the student to learn how to choose a suitable vector for gene analysis'. Educational aims can also be described for projects in general e.g. 'projects should enable students to think for themselves and use their own initiative'. We found that documentation about each project and discussions between student and supervisor focused on scientific aims, with educational aims being neglected.

> *Supervisors and others involved with the implementation of projects in the undergraduate curriculum should recognise the distinction between the scientific aims of individual projects and the general educational aims of project work. The educational aims of project work should not be neglected in project documentation and student-supervisor discussion.*

2.2 The major educational aims of project work

The three most important educational aims identified by supervisors in our survey sample are 'to help students to develop a critical attitude when working with data or scientific models', 'projects give students an insight into what science research is really like' and 'projects give students the chance to think for themselves and use their own initiative'. These aims emphasise the importance of introducing students to the processes of scientific activity. However, we found that many students have a restricted experience of scientific activity during their project. For example, many students are prevented from making progress owing to difficulties in making procedures work. Whilst such difficulties are typical of scientific research this is not the only aspect of life as a research scientist. Furthermore, many students who are working in isolation gain little experience of communicating their ideas to others - a key feature of scientific activity.

> *A major aim of project work is to introduce students to what it is like to be a scientist and to enable them to think critically about scientific ideas. Supervisors need to consider whether their students have access to a broad range of scientific experience. Supervisors can help by trying to ensure that students have some results to work with and by encouraging students to discuss project work with their supervisor, PhD students or other undergraduate students.*

2.3 The students' perspectives on the major educational aims for project work

All of the aims identified by supervisors were also mentioned in the student interviews. However, individual students tended to place different emphases on these aims. In particular some students placed greater emphasis on learning about general issues from their project work, compared with learning about scientific issues. This contrasted with interviews with supervisors all of whom tended to mention general aims after having discussed projects as an opportunity for students to learn about science.

> *Different students are looking to learn different things from project work. Some are concerned to learn about science whilst others are more concerned to develop their general abilities and impress future employers. Supervisors should try to establish what individual students are looking for from project work. This could be done through informal discussions or perhaps a more formal writing exercise. Though students desires should not necessarily dictate the direction of project supervision, knowledge of individual students will help supervisors in relating to students and addressing or anticipating student concerns.*

2.4 Should all students get the opportunity to do research projects?

During interviews with supervisors and workshops with lecturing staff the question of whether all students should do research projects was often raised. Projects are very expensive and time consuming to run. In the supervisor survey 71% of supervisors felt that *ideally* all students should be given the opportunity to do a research project in their final year. Furthermore, the student survey showed that 89% of students would rather do a research project in their final year than an extension of second year teaching laboratory work. Our student survey also showed that 70% of students found their project 'really interesting' with 32% feeling that 'it was the best part of the course so far - I really enjoyed it'.

> *Data from the interviews and surveys in this study emphasise that for the majority of students and supervisors project is a unique and valued part of the undergraduate course. Despite pressures of time and money there is a strong case for giving all students the opportunity to tackle a final year research project.*

Key references

Working Paper 3	Section 2
Working Paper 4	Section 3
Working Paper 7	Section 4

3 Types of project

3.1 Should undergraduate projects involve original scientific research?

In our study 'original scientific research' is characterised as research which has the potential to produce results which could be included in a research publication. Our survey of supervisors shows that there is an overwhelming belief that undergraduate research projects should involve original research. The two most common reasons given were that original research motivates students and that supervisors are more likely to work with a student if the project involves original research. Furthermore, the survey of students showed that 'working in a real scientific research area' was the third most commonly stated source of motivation for students.

> *To encourage student and supervisor motivation undergraduate research projects should involve original scientific research, even though this means that projects may be unpredictable in terms of direction and outcome. (An additional argument for projects involving original research in terms of what students can actually learn is made in section 8.1)*

3.2 The relationship between project type and students getting results

For the student 'getting scientific results' usually means achieving an outcome which goes some way to answering the research question which their project is addressing. Students are very concerned about whether or not they get scientific results from their project. There are two major issues behind this concern. Firstly, students often feel that without scientific results they will not be able to get a good mark (the issue of assessment is discussed in section 6). Secondly, students want to get results so that they feel they are making progress and are able to move on to the next stage of their project. In our student survey sample, 7% of projects yielded no results at all. Interviews showed that many supervisors try to devise projects which enable students to get some results early in the project in order to give the student confidence and a sense of progress.

> *Supervisors should try to devise projects which enable students to get some form of result early in their project. Supervisors also need to be aware that students may have very high expectations for the kind of results that they will get from their project.*

3.3 A way of characterising the types of projects available to students

Many students have very little idea about what work on their project will be like before they start it. In working paper 3 we characterise project type in terms of six dimensions. For example, one of these dimensions is whether or not the project involves original research (see 3.1 above). Another dimension is the

working environment in which the project takes place (see section 7.2 of this paper). These six dimensions capture the variety of student experience on project work and provide a way of describing to students the differences between different types of project.

> *Supervisors could give prospective students an image of what life would be like on a particular project by using the six 'project dimensions' outlined in working paper 3. This would help students to formulate realistic expectations of project work. It would also help students to choose projects suitable to them during the allocation process (see section 4.1).*

Key references

Working Paper 3	Section 3.2
Working Paper 4	Section 2.4
Working Paper 7	Section 5

4 Allocating projects to students

4.1 What information do students need to help them choose suitable projects?

In all of the departments involved in the study students are asked to choose from a list of projects those which they are most interested in doing. The project module manager must then allocate individual students with a project based on each student's list of preferences. In our student survey sample 82% of students were given a project which appeared in their list of preferences. Since the student chooses which type of project they will be doing, it is vital that they are given appropriate information about each project before they make their choices. In the survey, students identified 'the skills they would acquire' and 'working environment' as information which would help them make appropriate choices. Furthermore, the six dimensions which describe project type (see section 3.3) also highlight forms of information which are important to the student.

> *Students should have access to a broad range of information about each project. This information needs to go beyond specific details of the scientific content of the project to include the learning experiences the student will get from the project and the environment in which project work will take place.*

4.2 Sources of information - the project booklet

All students are given a booklet which describes each project and from which they must compile their list of preferences. In our survey 16% of supervisors (and 35% of students) felt that the content of the project booklet was unsatisfactory. Entries in the project booklet largely focus on the scientific details and neglect the educational aims of each project (section 2.1). However, lecturers felt that in any case students still need more information about projects than can be provided in the project booklet.

> *The information provided in the project booklet should place more emphasis on the educational aims of each project. Furthermore, it should be stressed to students that they need to get additional information about the projects which they are interested in*
>
> *(N.B. It may be possible to provide further information about projects on the World Wide Web. This would avoid unnecessary photocopying, and allow supervisors to provide students with substantially more information than is possible in the project booklet).*

4.3 Sources of information - visits to supervisors

Two thirds of the students in our survey sample made visits to supervisors before deciding on their final list of preferences. Of these students 18% stated

that these visits had not been useful. Supervisors in the survey identified two valuable aspects of visits: students get the chance to meet the supervisor and decide whether or not they could work together, and students learn more about the project than is possible from the project booklet. The importance of the student-supervisor relationship is explored in section 5 of this paper.

> *All students should be strongly encouraged to visit prospective supervisors. These visits should give students the chance to meet the people with whom they would be working and include a visit to the area in which they would be working.*

4.4 Methods used by module managers to allocate projects to students

Once students have generated their list of preferences the departmental module manager must decide which students get which project. Of our student survey sample 63% were allocated their first choice project, and 90% stated that they were happy with the project allocated to them. Most students had no idea about how they were allocated to projects. A few students expressed considerable disquiet about how they *thought* module managers decide who gets a first choice project. Supervisors stated that if more than one student puts a certain project as their first choice then in many cases the student with the highest previous examination marks will be allocated the project.

> *The methods by which module managers allocate projects to students should be made clear to students.*

Key references

Working Paper 3	Section 4
Working Paper 4	Section 3
Working Paper 7	Section 6

5 The supervision of projects

5.1 The nature of the student-supervisor relationship

The case studies and the surveys all show that a positive student-supervisor relationship is vital if a project is to be a successful learning experience for the student. Students in the survey most often described 'a positive and friendly relationship' as the best aspect of their supervision. A positive relationship encourages a reliable and continuous exchange of information. This helps to avoid misunderstandings of the kind described in the case of Carol and Dr Rochester in working paper 6. Here Dr Rochester felt that the project had been very successful despite the fact that Carol stated that she had learnt very little from the project and had found it very difficult to talk to her supervisor. Indeed, 20% of the students in our survey sample gave responses which indicated that their relationship with their supervisor had been poor.

Our analysis of interviews with students and supervisors identified 3 areas which, if considered by the supervisor, can help to develop a positive student-supervisor relationship:

1) An awareness of the students' expectations of the project
2) Making reasonable demands of the student
3) Being aware of the student's level of motivation and taking steps to increase student motivation towards their project.

> *Supervisors must recognise that their role goes beyond that of a guide through the technical aspects of project work. Supervisors must also consider the human side of project supervision. Although the nature of the student-supervisor relationship cannot be 'engineered' there are steps which the supervisor can take to make a positive relationship more likely to develop.*

5.2 The role of PhD students and postdoctoral researchers

PhD students and postdoctoral researchers are an important source of guidance for many students. Of our student survey sample 40% reported that PhD students and/or postdoctoral researchers were *more involved* in their supervision than the lecturers assigned as supervisor. Furthermore, the fourth most common aspect of good supervision mentioned by students was that involving PhD students and/or postdoctoral researchers. PhD students and postdoctoral researchers can provide a different type of supervision to that from the lecturer assigned as supervisor. For instance the case of Julia described in working paper 6 highlights the positive social environment which PhD students and postdoctoral researchers can provide. Such informal social interaction can enable the student to learn a great deal about how research takes place. However, there are cases where friction develops between PhD students/postdoctoral researchers and the student. This is often because the roles of those involved is unclear.

Whenever possible PhD students and postdoctoral researchers should be encouraged to become involved in the supervision of undergraduate project students. However, it is important that all involved are clear about their roles in project supervision. The supervision of project students should be considered as one aspect of the professional development of PhD students and postdoctoral researchers.

5.3 The content of student - supervisor discussion

Students and supervisors identified the interpretation of results and technical advice about how to overcome problems as major areas of discussion. Students valued this discussion which is very important to their progress through the project. However, interviews with students also showed that discussions 'beyond the science' were extremely important.

Supervisors should ensure that the following issues (in addition to purely technical matters) are included in discussions with students from time to time:

a) What the student feels that they should do next on the project.
b) Whether the student feels that they are doing well on the project.
c) The supervisor's judgement about whether the student is doing well on the project (in terms of the departmental assessment criteria).
d) The student's workload.
e) The place of the student's research within an active scientific research programme.

Key references

Working Paper 3	Section 5
Working Paper 4	Section 4
Working Paper 6	Sections 3 and 4
Working Paper 7	Section 7

6 The assessment of projects

6.1 Students need to understand how their projects will be assessed

Our case studies show that some students tend to underestimate how well they are performing on their project. Students also reported that their biggest source of motivation was a personal desire to get a good mark for their project. Given the importance of a good mark to the student, an inaccurate self-assessment can lead to low morale. One of the major reasons for inaccurate personal assessment is the students poor understanding of how projects are assessed. A third of students in our survey sample stated that they were only *vaguely aware* of how their project would be assessed within three weeks of the end of their project work. Students would like more information about how their projects are assessed whilst they are working on their project. Furthermore two thirds of our supervisor survey sample felt that students should be shown the assessment sheets used in the department, and 54% felt that project assessment should be discussed in final year tutorials.

> *Students should be provided with formative assessment through their project. This could be done using mock assessment interviews. Students should also be shown the departmental assessment sheets and tutors should be encouraged to discuss project assessment as part of the final year tutorial programme.*

6.2 Many students believe that project assessment depends on whether they get scientific results

Interviews with students show that many feel that unless their project yields scientific results they will not be able to get a good mark. As a result many students become stressed and overworked because they feel that they have to get results, even if this means neglecting other module work. This is in spite of explicit statements in departmental literature and by supervisors that results don't matter. Students cannot see how it is possible to demonstrate their full abilities at data interpretation and other stages in their project, if they spend all of their time trying to solve problems with a single technical procedure.

> *Departments need to ensure that their assessment methods allow good project work by students to be awarded a top class mark even when the project is unsuccessful in terms of scientific results. Departments also need to convince students that this is how their assessment system works. This could be done by giving students examples of previous projects which have not obtained results but which have been awarded a first class mark.*

Key references

Working Paper 3	Section 6
Working Paper 4	Section 6
Working Paper 7	Section 6.3

7 Students' experiences of project work

7.1 Preparing students for project work

Our twelve case studies show that many students feel unprepared for project work. This leads to a very stressful and confusing first few weeks of project work. Indeed, this confusion can extend well into the project. Students are unused to three aspects of project work: the subject area, the work pattern of project work, and the working environment in which the project takes place.

In the survey students highlighted four areas which would help them to be better prepared for project work:

1. Practice at reading scientific research papers
2. Talking with students who had just completed a final year project
3. Mini-projects earlier in the course
4. Activities in which they can gain confidence in interacting with lecturing staff

> *Departments should try to incorporate aspects of the four areas identified above into the undergraduate curriculum. Furthermore supervisors should be aware that students are confused about the work pattern and working environment in addition to the subject area of project work.*

Key references:

Working Paper 4	Section 7.1
Working Paper 7	Section 6.2

7.2 The project working environment has a major impact on the student's experience of project work

Project work is undertaken in a wide range of different working environments. Whilst the majority of projects take place in an active research laboratory, many involve the student working alone, amongst student peers (particularly in Earth Sciences), or in the library. Our study has shown that all such working environments have their merits and disadvantages. However, individual students are likely to find some working environments highly suitable and others highly unsuitable. The case of Julia reported in working paper 6 is an example of a student being particularly suited to working within a lively and social research laboratory. Other students enjoy working largely alone. The case of Carol reported in working paper 6 is an example of a student having a poor learning experience partly because she is too isolated from peers and other researchers.

During the allocation stage students need to be aware that projects can take place in widely differing the working environments. They need to reflect on which working environment they are most suited to, and make their choices accordingly. Departments also need to provide students with information about project working environments. During project work supervisors need to be aware that many students may struggle to adapt to the project working environment. In those cases where students are working in isolation, some students may benefit from formal activities which encourage them to talk about the progress of their work. One way of doing this is through peer tutorials.

Key references:

Working Paper 6	Sections 3 and 4
Working Paper 7	Section 5.2.2

7.3 Workload and time management

Our study indicates that the vast majority of students work longer hours on their project work than they are supposed to. This causes stress and neglect of other module work. The main reasons for this overwork are the long term nature of some experimental procedures, pressure from those associated with the project and the personal desire to get some scientific results. Students are unused to organising their workload over an extended period of time. However, despite the need to learn about time management, 60% of our student survey sample reported that they never talked about time management with their supervisor.

Departments need to be explicit about the amount of time students are expected to work on projects. Where students need to work long hours during a particular phase of project work supervisors should encourage students to take time off later on in order to make up for lost work on other modules. In those projects involving PhD students or post doctoral researchers, supervisors should ensure that students do not feel undue pressure to work longer hours than expected. Students should discuss time management issues with supervisors. Supervisors should encourage such discussions and recognise that one of the aims of project work is to enable students to learn how to manage their own time.

Key references:

Working Paper 4	Section 5
Working Paper 7	Section 8

7.4 Student control over the direction of project work

The twelve students in our case studies each had a very different degree of control over the direction of their projects. Some students suggested new lines of enquiry following their own literature searches, whilst others tended to follow the direction set by the supervisor. It was also clear that individual students *prefer* different levels of control. Not all students are happy to be given the chance to control the direction of their project. However, by the end of projects most students said that they enjoyed having some degree of control over project direction. During interviews, supervisors reported a variety of techniques which they had learnt from experience can encourage the student to take more control over the direction of their project. Some supervisors also recognised that they had a tendency to be too prescriptive with their project students.

> *Supervisors need to be aware that individual students require different levels of guidance at particular stages in their project. It is important that students are encouraged to take an appropriate degree of control over their project, particularly if the student already has some scientific results to work with. One way of doing this would be to regularly ask students 'what would you do next' during supervision sessions.*

Key references:

Working Paper 3	Section 5.3
Working Paper 4	Section 8.3

7.5 Students' experiences of preparing their final report

During the final interviews many students reported the difficulties that they had experienced in preparing their final project report. These difficulties arose from the small amount of time in which they tried to write the report and their lack of experience in preparing such extended reports. Our survey data shows that nearly half of the students were dissatisfied with their final report. Of these students, two thirds felt that this was the result of poor time management.

Students need to be aware of how long it can take to write the final report. Devising ways in which they have the chance to talk to former project students may be an effective way to do this. Supervisors need to encourage students to prepare parts of their final report during the project. Supervisors also need to make it clear to students that they should stop project work early enough to enable them to make their final report their best effort.

*(N.B. One way of getting students to realise that writing a final report needs to be planned for would be by showing them a **video** of students talking about the difficulties that they had in preparing their final report on time, and the things that they wish that they had done earlier in their project. Indeed case study material presented through video could be used to exemplify many of the recommendations described in this paper. Furthermore, students could be shown good reports completed by previous students. Supervisors could explain why these reports are considered to be exemplary.)*

Key references:

Working Paper 7 Section 8.2

7.6 Students' overall feeling and motivation towards project work

Our survey data provides an overview of how students feel about project work. Three quarters of the student sample found project work 'really interesting' and one third found projects 'the best part of the course so far'. By contrast, 1 in 8 students reported having 'a dreadful time' on their project. This shows that students have enormously different feelings about their project work. The reasons for this spread are complex and depend on the students themselves, the effort they put in, the nature of supervision and whether or not the project yields experimental results. Further discussion is given in the working papers.

The students' written responses to the open questions concerning the best and worst part of project work and their advice to future students, indicate those areas which have a major impact on student motivation. These issues seem to group around four key areas:

1. Getting scientific results
2. The relationship between student and supervisor
3. Careful time management
4. Interest in the scientific content of the project

The findings briefly described above suggest that projects are an important and valued part of the undergraduate curriculum, and should be made available to all students. However, steps need to be taken to try and reduce the number of students for whom project is a 'dreadful time'. The four areas described above indicate that students are more likely to be motivated towards project if they get some scientific results early in the project, have a positive and relaxed relationship with those involved in their supervision, are encouraged to manage the use of their time throughout the project, and are engaged in a project which involves original research in an area which the student sees as relevant and interesting.

Key references:

Working Paper 4	Section 7.3
Working Paper 7	Section 9

8 Students' learning about science through project work

8.1 What do students learn about science during project work?

In working paper 1 we identified five main areas of science learning:

1. Subject matter knowledge
2. The nature of scientific knowledge
3. The processes of scientific enquiry
4. Craft knowledge
5. Scientific culture

Interviews with students and supervisors show that student learning during final year undergraduate research projects largely focuses on areas 2 to 5. This coverage demonstrates the unique character of research project work within the undergraduate curriculum.

One aspect of student learning during project work which includes parts of areas 3 and 5 is the student's development of a 'broader view' of their project. As discussed in the working papers, a broader view involves seeing how an undergraduate project fits in to an ongoing, often global, research programme. However, many of the twelve case study students had not developed such a broader view of their project by the end of their project. Some students still tended to see their research project as something dreamt up by their supervisor without reference to any external scientific influences.

Another key aspect of student learning during project work focuses mainly on areas 2 and 4 above. In almost all cases students were surprised at how difficult it was to collect reliable scientific data. Their previous experiences in the teaching laboratory had not prepared them for this. Many students come to realise that equipment and procedures often need to be 'tweaked' many times before the required information can be obtained (an example of craft knowledge). Most students were unprepared for this and became demoralised if they were unable to generate results within the first few weeks. Furthermore, even when results are forthcoming students are often surprised at how difficult it is to interpret these results. Many students reported specific incidents which developed their views about how scientific results are used to develop theoretical understanding. This important issue is explored in working paper 5.

Supervisors need to ensure that their students develop a broad understanding of the nature of scientific research across all of the five areas of learning identified above. For example, students should realise how their project fits in to an ongoing research programme.

(N.B. The use of case study material recorded on video as discussed in section 7.5 could be useful here. Video could be used to illustrate the many ways in which supervisors can encourage students to think about the nature of scientific research.)

8.2 A view of how students can learn about science during research projects

In working paper 1 we presented a view of learning through 'enculturation' in which the student learns about science by being amongst practising scientists, talking with them, and engaging in aspects of scientific work under their guidance. Final year research project work is a context in which this view of learning seems particularly appropriate. The cases of Susan and Julia reported in working paper 6 are typical of those students who learnt about science by talking with practising scientists - either PhD students, postdoctoral researchers or lecturers. In these cases the working environment and the student-supervisor relationship were particularly well suited to learning through enculturation. However, not all students were able to learn about science in this way. The case of Carol in working paper 6 highlights the problems that can occur for student learning about science when both the working environment and the student-supervisor relationship do not support an enculturation into science.

Departments need to be aware that student learning about the nature of scientific research can be supported by very informal mechanisms such as students simply talking about science research with a practising scientist. For those projects in which students are unable to interact continuously with practising scientists departments may need to engineer more formal opportunities for students to talk about science. One possibility is to use peer tutorials in which students meet up with other students at regular intervals to discuss their shared experiences of research project work.

Key references:

Working Paper 1	
Working Paper 4	Sections 8.2 and 9
Working Paper 5	
Working Paper 6	Particularly sections 2.4, 4.5 and 5.1

Appendix 1: 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 science research projects and students' images 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 Three case studies of student and supervisor experiences during undergraduate science research projects

These 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 A summary of findings and recommendations 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.

The Centre for Studies in Science and Mathematics Education University of Leeds

The Centre was established in 1970. It is involved in the initial training of teachers of science, mathematics and technology as well as preparing candidates for the degrees of MEd, MSc in Mathematics and Mathematical Education, MPhil, EdD and PhD. It is known internationally for research and scholarship with particular interests in the fields of assessment and evaluation, science education policy, learning, the public understanding of science, teacher education and technology education. The Centre offers a wide range of in-service courses for teachers as well as tailor-made courses for teachers and others involved in science, mathematics and technology education from a number of countries outside the UK.

The Learning in Science Research Group

Work on teaching and learning science at the University of Leeds has a long history. The Learning in Science (LIS) Research Group is made up of science educators with interests in all aspects of teaching and learning science, including science education at all stages of schooling, undergraduate science education, and science communication in informal settings. Research into teaching and learning science in schools forms a major part of the LIS research programme - building upon the work of the Children's Learning in Science Research Group which started at Leeds in the early 1980's. The Learning in Science Research Group currently receives financial support from the University of Leeds, the University of Leeds School of Education and departments in the Faculty of Science at Leeds, as well as having a number of externally funded research projects.