Essay

What can students learn from final year research projects?

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Abstract

Final year research projects are a feature of most biosciences undergraduate courses. However, in a climate of increasing student numbers there is growing interest in providing alternatives to such resource-intensive projects. This interest raises some key questions. In particular, what do students learn from traditional final year projects and can alternative teaching activities be found to achieve all or some of these learning aims? This report follows from a recent Learning and Teaching Support Network (LTSN) Biosciences workshop held in the UK: 'Alternative Final Year Projects'. At the start of the workshop results from an educational research study were used to present a characterisation of student learning on 'traditional' final year research projects. This report summarises these findings and aims to promote a broad discussion about what traditional projects achieve, and what alternatives might be able to offer.

Keywords: research projects

Introduction

In December 2003, the Learning and Teaching Support Network (LTSN) for Biosciences in the UK held a one day session entitled 'Alternative Final Year Projects: There's more than one way to skin a cat!'. The workshop was a response to a growing tendency to consider alternatives to traditional final year research projects. Traditional projects typically involve students working over a long period of time, alone or in small groups, on small-scale research. Projects are often related to the research interests of the supervising lecturer. However, such projects tend to be very resource-intensive. Often data is collected within a research laboratory with students working alongside PhD students, postdoctoral researchers and established academics. The student needs close supervision and the project may involve the use of expensive laboratory equipment. As student numbers continue to increase, many departments are considering replacing such research projects with alternative learning activities (or have already done so), at least for some students. Speakers and attendees at the workshop in Manchester described many innovative and interesting alternative activities, e.g. preparing a grant application to a science research funding body, and students drafting media reports to communicate scientific findings (and evaluating the impact of such reports). However, a key question for the workshop was 'What learning outcomes from traditional final year research projects are these alternatives seeking to achieve?' This report provides one characterisation of these learning outcomes based on findings from an educational research project that examined students' experiences of traditional final year research projects.

The Research Project Study

The Research Project Study was one of a number of studies undertaken by the Undergraduate Learning in Science Project (ULISP)[1]; a collaboration between the School of Education and science departments at the University of Leeds. A sample of 12 students of different levels of attainment, gender and project type was selected from four science departments (including two biosciences departments). No attempt was made to generate a sample representative of the student population as a whole. Rather, our aim was to use a small number of detailed case studies to investigate the breadth and diversity of individual student's experiences. Examples of the focus of student projects include the isolation and purification of a plant protein for future sequencing, and the search for patterns within a genetic database. For most of these students their project experience was the first time that they had investigated a problem to which nobody else knew the answer.

The research design is summarised in Figure 1. Students were interviewed at three points over the 8 month period of their project. They kept personal diaries of their experiences and were also visited by researchers as they worked on their projects. Supervisors were also interviewed about their experiences of the student's project work at the end of the study.

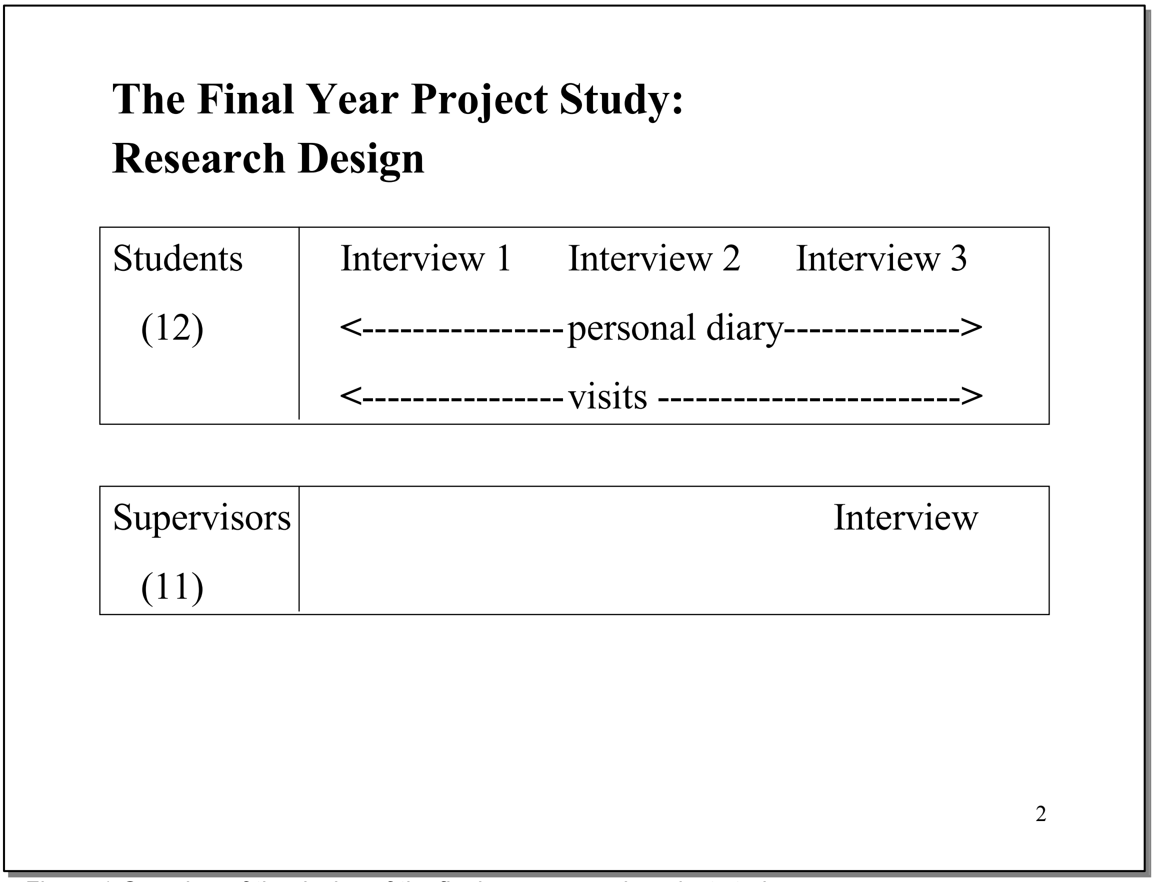

Figure 1 Overview of the design of the final year research project study

1 Further details and publications available at http://www.education.leeds.ac.uk/research/scienceed/undergrad.htm

The first and final interviews addressed students' experiences of their project work and included the following questions.

- How do scientists decide which questions to investigate?
- Why do scientists do experiments?
- How can good scientific work be distinguished from bad scientific work?
- Why do you think that some scientific work stands the test of time whilst other scientific work is forgotten?
- How are conflicts of ideas resolved in the scientific community?

These questions were designed to encourage students to talk about their understanding of professional science research. Students were encouraged to refer to what they had learnt from their experiences on research projects. Responses to these questions before and after their projects provide insights into student learning about the activities of professional scientists. A detailed analysis of students' responses to these questions has been published elsewhere (Ryder, Leach, & Driver, 1999).

What students learnt from their research projects

Table 1 provides a characterisation of student learning as a result of their experiences of final year research projects. It is based on the analysis of the five questions above, and also what students reported that they had learnt from project experiences. Table 1 provides an overview encompassing all of the students involved in the study; few students demonstrated learning across all of these areas.

Table 1 A characterisation of student learning outcomes from final year research projects

Knowledge of science
Scientific concepts, theoretical models…

Knowledge about science

Methods of scientific enquiry
Design of an experimental/computational study
Developing experimental expertise
Problem solving in the context of their study
Learning the 'tricks of the trade'
Origins of lines of scientific enquiry
How do scientists decide which questions to investigate?
The influence of personal curiosity
The role of previous scientific enquiries
The impact of funding bodies and commercial interest

Relationship between knowledge claims and data
Potential for multiple interpretations of data
Role of judgement/experience in interpreting data
The uncertainties and limitations of scientific investigation

Culture of scientific research
Professional working environments and activities
Role of journals
Professional science institutions
Career development opportunities
Ethical/legal implications
Technical support structures
Research areas of the discipline

General Skills
Time management
Use of initiative
Creative thinking
Communicating results
Personal organisation
Adapting to an unfamiliar environment
Realistic assessment of their own performance

Knowledge of science refers to the concepts and theories of science. Working on their projects students drew upon, and applied, science knowledge they had first encountered during lectures and tutorials. In many cases students needed to learn new science concepts and theoretical ideas. This knowledge of the ideas of science can be contrasted with *knowledge about science*: knowledge about the development and use of scientific knowledge. Such a distinction is sometimes described in terms of product (knowledge of science) and process (knowledge about science) (e.g. Finn & Crook, 2003). However, it is important to recognise that knowledge of/about science are inextricably linked. For example the details of learning about the design of an experimental study (knowledge about science) will depend on the science content area in which the study will take place (knowledge of science).

The following sections provide exemplification of the learning outcomes presented in Table 1.

The methods of scientific enquiry

Here is how one supervisor described what she wanted students to learn about the methods of scientific enquiry from final year research projects.

> *[Students] appreciate the overall strategy of scientific work, of identifying the problem, planning a strategy to solve it, 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.*

This illustrates a striking breadth of intended learning outcomes. Many of the students in our sample were indeed involved in the design of a research study, although many lacked an overview of the relationship of their small-scale study to a broader science research programme (at least at the beginning of their project work - see below). Those engaged in the collection of data, either in a laboratory or in the field also learnt a great deal about the technical details of gathering reliable data in challenging circumstances. Students commented that such experiences were a long way from the 'cook book' practical investigations they had been engaged in previously on their course. A key learning outcome for such students was the recognition of the need to develop 'tricks of the trade' (not to be found in laboratory/user manuals) when using investigative apparatus in contexts at the edge of current scientific understanding. The following quote gives one student's reflections on his learning about the methods of scientific research.

> *Because the understanding of Biochemistry isn't just doing Biochemistry, learning techniques from a blackboard, from a lecture theatre. You have to get hands-on experience of how all this has been found out, how it has all been deduced (...) you have to get more of an understanding of what Biochemistry actually is.*

This student is describing how she had learnt about ‘how we know what we know’ in the biosciences.

Origins of lines of scientific enquiry

Many students had little insight into the origins of the research work that they were involved in, at least at the beginning of their project work. Most thought that their supervisor generated areas for student research in much the same way that they thought up examination questions. What was missing for these students was some understanding of how science research builds upon earlier investigations and ideas forming ‘lines of scientific enquiry’. Professional scientists pursue such lines of enquiry over a long period of time, in response to personal curiosity and subject to available funding. All of the research projects followed by these students arose from the supervisor’s own lines of scientific enquiry. Of the six students who showed little understanding of how their research project related to a line of scientific enquiry at the beginning of their project, five of these had developed such insights by the end of their project work.

Relationship between knowledge claims and data

Studies involving school science pupils show that young people often view science knowledge as a collection of 'hard facts' (Driver, Leach, Millar, & Scott, 1996). Students with such a view tend to see the collection of data as leading unproblematically to accepted science knowledge. For example when asked about how scientists might establish whether or not global warming was taking place one school pupil suggested that this was easy: simply attach a thermometer to an airplane and measure the temperature of the atmosphere! However, such a view misses the inherent variability involved in empirical measurement, the complexities of the phenomenon involved, and also the potential for a single data set to be interpreted (legitimately) in multiple ways. Here is how one project supervisor described what he wanted students to learn about the relationship between knowledge claims and data from final year research project work:

> *[A project] 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.*

Views about the relationship between knowledge claims and data varied a great deal amongst the final year university science students involved in our study. This variation is illustrated below using student responses at the end of their project work to the question 'How are conflicts of ideas resolved in science?'

> *How they resolve [conflicts] in science is by carrying out experiments that prove one theory is right, proving without a shadow of doubt that theory is the correct one*

Taken together with other responses during this student's interview it is clear that she thought that where conflicts of ideas arise these can be resolved unproblematically using empirical data. Such a view contrasts with that of the following student who recognises that in many cases several distinct theoretical models can be used by scientists to interpret the same phenomenon.

> *Well it's often that at least two or three theories will always be there to explain a phenomena, until maybe it's proved experimentally. But even then people can change around their theory (...) you can have a number of separate theories (...) running along side.*

Following their experiences of final year research projects a number of students developed their views in this area. This was typically because these students became familiar with the different theoretical perspectives in the subject area of their own project work (through discussions with researchers and/or reading of the scientific literature). They also recognised that despite years of empirical scientific investigation many conflicts of ideas at the frontiers of science remain unresolved.

Culture of scientific research

Many of the students involved in our study were working within university research laboratories alongside postdoctoral researchers, technicians and

PhD students. Students were sometimes invited to attend research seminars within the group. Through these experiences there were many opportunities to learn about what a professional science researcher does on a day-to-day basis. Here is how one project supervisor described this aspect of the final year project experience:

> *They can get the possibility of going into an actual research lab. and experiencing within an active research group what it's all about: the pitfalls, the trials, the tribulations as well as the excitement whilst on the research.*

As reflected by the following student, learning about the culture of science can help students in making appropriate career decisions.

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

General skills

Students also reported that they had learnt many skills not specific to science. For example, here is how one student reflected on the purposes of final year projects:

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

Such skills, whilst learnt within a science context, were seen by students and supervisors as applicable more broadly.

Discussion

Table 1 provides a characterisation of student learning outcomes for a small group of students from four science departments at one university. It is possible that choosing a different set of 12 students would give rise to different emphases and perhaps additional learning outcomes. Furthermore, looking at final year project work at a different institution may result in a different set of learning outcomes. Despite these caveats, Table 1 can provide a starting point for discussions within university departments about the learning outcomes of existing final year project work. Departments then need to decide which learning aims they feel it is essential for all their students to achieve, and which learning outcomes are essential only for a subset of students (perhaps those considering continuation into a PhD). Such considerations might then lead to the design of a suite of alternative teaching activities.

The LTSN Biosciences Manchester workshop included presentations of alternatives that were clearly very good at achieving some of the learning outcomes in Table 1, but were unlikely to develop student understanding in other areas. For example, a teaching unit that involves students in writing a research grant application is likely to develop student understanding about the origins of lines of scientific enquiry and perhaps the ethical implications of research design. It will also involve skills related to communicating scientific ideas through writing. However, such project work may be less successful in providing insights into problem solving within a challenging experimental study. However, this selective success across a range of learning aims may not be so different from practice with traditional final year research projects. Our study showed that depending on the nature and progress of the project student learning was often confined to particular areas. For example, several students achieved no usable experimental results over the period of their project. Such a project is likely to emphasise the problem solving aspects of investigative work rather than learning about the relationship of knowledge claims to data.

Finally, whilst this report has focused on student learning outcomes, a distinct and very significant outcome for many students was in terms of motivation and ownership:

> *[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. [Lecturer]*

> *It's your little baby kind of thing and you do get really interested in one particular little aspect of science, whereas if you're working on different experiments every week, it's just another experiment isn't it? Nothing exciting. But [with project work] you do get into what you're doing. [Student]*

How might alternatives to traditional final year projects impact on student motivation and sense of ownership?

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