Igniting students: Do Large-scale Undergraduate Research Projects Enthuse or Defuse?

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INTRODUCTION

The chemistry honours school at Oxford University is large, with an annual intake of around 190 students. The final year of the degree consists entirely of a prolonged period of research, providing students with first hand experience in the development of scientific understanding, and experience in the scientific method. It is this year of research, and in particular the question of whether such extended undergraduate research is valuable or counterproductive, which is the subject of this paper. A number of comments from current students are included, and are set off from the text in contrasting colour.

1 The structure of the chemistry degree

Many chemistry departments, particularly those in the USA, teach a large cohort of first year students. Service teaching for pre-med students, biologists and others who need a grounding in chemistry is an important part of the teaching load in most North American Universities, and may lead to freshmen classes of five hundred or more.

Service teaching on such a scale is uncommon in Britain, and by comparison first year enrolment in the Oxford chemistry program is modest at less than two hundred students. However, all the students specialise in chemistry, and in terms of honours students, Oxford is among the largest chemistry departments in the world. More than 500 people are engaged in research, and the department is large both in the context of Oxford University, and on an international level.

Undergraduate research is carried out alongside graduate work in most groups, where it makes a significant contribution, although a turn of the century Oxford Professor of Classics might not have thought so, having commented:

> "Show me a researcher and I'll show you a fool."

The undergraduate degree is broken into two parts. During "Part I", which occupies the first three years, students follow a traditional chemistry course, attending lectures, classes and practicals in each of the main branches of the subject. The syllabus is biased towards chemistry, rather than cross-disciplinary subjects, and is probably both narrower and deeper than its transatlantic counterparts. However, contributions from physics, biology and mathematics, with options in pharmacy, history & philosophy of science and other areas, help to broaden the course. Overall, the syllabus has much in common with chemistry programs worldwide, although the practical course occupies less time than in many Universities.

> " [in Part I] you don't do that much hands-on chemistry; most of the experiments in (in)organic chemistry are very similar, and ... not that interesting."

Conventional teaching is supported by the Oxford tutorial system, in which each student meets every week with at least one member of the chemistry faculty, who is also a member of the student's college, to discuss their work and progress.

In a "big bang" culmination to Part I, exams which cover the whole three-year lecture course, and consist of eight written papers, are taken in the space of around five days by all students. These exams contribute 75% of the mark which will determine the final class of degree. There is no continuous assessment.

This concentrated examination period can increase the pressures on the student:

> "I would have preferred a system whereby some of the lectures from Part I were conducted in Part II... Having exams spread over two years would also decrease the pressure over any one exam period."

The entire fourth year ("Part II") is devoted to research. Part I terms are short and exceptionally intense (each of the three terms per year lasting just eight weeks), but the Part II year is extended, running from early September to late June the following year, with only two short breaks. Part II is thus broadly comparable on its own to an MSc "by research" and indeed the degree which is awarded at the end of the four-year course is an MChem, not a B.Sc.

Students can, if they wish, leave at the end of their third year with an unclassified degree, but the number who do so voluntarily, or are required to do so because they have failed the Part I exams, is very small, typically around 1 - 2% of the school; thus effectively all students who complete Part I also undertake Part II.

Although Part II has been part of the chemistry degree for many years, it has not been without its detractors. An obituary of WH Perkin junior in *Nature* in 1929 commented:

> "The act by which Perkin jun. made himself most noteworthy in the University of Oxford was in securing the provision of a fourth year, to be spent in learning the methods of research, as necessary for the honours degree. It is a grave question whether this be a wise provision. It involves the assumption that the years previous to the fourth are not years in which the spirit of inquiry is inculcated and rampant. They should be - yet, if they were, it would not be necessary to set aside the fourth year for the purpose."

which makes one wonder whether the spirit of inquiry in our present-day research students is "inculcated and rampant".

Towards the end of their research year, students prepare and submit a thesis on their work, and have an oral examination. The final class of degree is determined by combining Part I and Part II marks in the ratio of 3:1. The Oxford Chemistry course is unusual in the emphasis placed on research, and the extended project has advantages and disadvantages for both students and the chemistry department, as we shall see.

2 The Choice of Supervisor - Who to work for?

The most crucial choice a student must make is that of which research group to join. Even for a brief project, this choice is important. Since Part II lasts an entire academic year, it is vital that students select a project in an area in which they have ability and a strong interest, and a supervisor with whom they can establish a sound working relationship. The student is the best judge of this, so the choice of supervisor is essentially entirely theirs. We do not try to persuade students to work in a particular area of science, (even though, as fashion swings from one area to another, there is often an uneven spread of students across the chemistry sub-departments).

Term	Action
Michaelmas, week 1	**Students issued with detailed information on how to select a supervisor for Part II, and given details of research web pages and Open Days.**
Michaelmas, weeks 1 - 8 **Hilary, weeks 1-4**	**Open Days for students in the different sub-departments; students explore possible projects and supervisors**
Hilary, week 4	**Deadline for submission of choice of supervisor**
Hilary, week 5	**Most students informed of their Part II supervisor**
Note: Michaelmas term is the equivalent of the Fall term in most Universities, Hilary term is the equivalent of Spring term, and Trinity is the Summer term.	

The timetable for selecting a supervisor (Table 1) provides half an academic year for students to meet faculty and discuss with them what Part II projects in their research group involve. There is thus ample time for students to investigate all the opportunities.

A wide choice of supervisors exists, with research interests covering all the major areas of chemistry. Students who have developed interests outside chemistry can (with prior approval) work in other departments, such as Materials Science, Molecular Biophysics, Physiology, Biochemistry, University Teaching Hospitals, History & Philosophy of Science, Physics, etc.

Recently, the chemistry sub-faculty agreed in principle that students should also be permitted to spend their research year abroad, and it has further been proposed that students from other Universities might be given the chance to spend a research year doing Part II at Oxford. For further information about this research year contact the author. The great majority of students, however, choose to remain within chemistry.

Students can access outlines of supervisors' research programs through the web, but such data give only a snapshot of current research, and students will talk to many potential supervisors and to members of their groups before making their decision.

Some projects naturally appear more enticing than others. The research topic may seem sexy and exciting, the supervisor approachable, the underlying theory understandable, and so on.

> "I have covered in depth topics like electrochem, XPS, solid state, conduction etc and because there is not the time pressure of Part I, I feel I have understood them better."

Other factors also enter into the equation. The supervisor's group may be well funded and offer the possibility of a period of work or conferences abroad. The research may be in an area of special appeal, such as in the Archaeological Laboratory (which has in the past handled such projects as the dating of the Turin Shroud) or History and Philosophy of Science (projects in which make use of Oxford's Museum of the History of Science and its wide range of other specialist libraries). Students have a varied list of project requirements, and their choice of potential supervisors is correspondingly broad.

Part II students can make a substantial contribution to the research effort of a group, and to spread the benefit each supervisor can accept a maximum of four students.

3 Open Days

The chemistry department is of sufficient size (numbering around 1,500 students, faculty and staff) that it is divided into separate organic, inorganic, physical/theoretical and chemical crystallography units, each with its own building. The three main sub-departments run Open Days, during which departmental research is outlined, and faculty members are available for consultation. In my own department (Physical and Theoretical Chemistry), the Open Day is supported by Shell Research, and culminates in a gathering at which students, faculty and members of their research groups meet informally over wine. Such an occasion helps students begin to appreciate the transition they are shortly to make from being mere consumers of information to being full members of active research groups.

4 Allocations

In the middle of Hilary term in the third year students submit their choice of up to three supervisors for Part II, in order of preference. A list of those who have nominated a particular supervisor is then sent to that faculty member, who decides to whom they will offer places. Those students not placed with their first choice supervisor are passed on to their second, and if necessary third, choices. A few students, unable to find a place with any of their three choices, subsequently reapply; eventually all students are accepted into suitable groups. The process of allocation is largely complete within seven days of the deadline for choices.

5 What does a typical research project consists of?

Appendix 1 lists a large number of recent Part II projects. The titles reflect the range of opportunities available to students in their fourth year.

Occasionally, students express a desire to devise their own project, but at the start of Part II few students, fresh to research, will know what problems need to be solved in a particular area of chemistry, and whether it is possible to solve them within the time constraints of Part II. Consequently, the supervisor determines the principal area and direction of the research. However, as the project proceeds, the student takes increasing control of its direction. Learning how research evolves is an important part of the training which students receive during the year, for many as important as the training in research methods.

The projects span a broad range, and so too do the types of work in which students engage. Most students join experimental groups, so develop synthetic, spectroscopic and other practical skills. A substantial minority work on computational, theoretical and other non-experimental projects. In whatever field the project lies, students work full-time on research and are expected to behave in all respects like graduate or postdoctoral researchers.

> "It is hard .... you have to put in lots of hours in the labs. Early morning lie-ins when you could miss random lectures are a thing of the past."

Thus, many students will be asked to give seminars or informal talks, most will contribute to the preparation of scientific papers for publication. They are expected to maintain lucid and accurate notes of their work, and to maintain the highest standards of scientific integrity.

6 Where does the money come from?

Research students swallow money. A theoretical chemistry student may eat fewer pounds than one in organic synthesis, but neither is free, and the question of how to meet the costs of undergraduate research is one which will have vexed many departments in which research forms a part of the course.

The immediate costs of a Part II student are absorbed by the groups in which they work, but there are extra charges for chemistry as a whole. The costs of liquid nitrogen, liquid helium, solvents, electricity, printing and photocopying, computing services and supplies amount to a significant sum. Without some form of support from the University it would be hard to maintain a large undergraduate research program.

Experience at many Universities (and doubtless also the evidence provided by other papers in this conference) has shown that undergraduate research is not only a valuable part of teaching, but also makes a material contribution to the overall research effort. This dual purpose justifies support from the University, and in Oxford this comes in the form of an addition to the block grant the administration allocates to chemistry. This contribution is roughly £2,500 (about $4,000) per student per year, so adds between $600,000 and $800,000 to chemistry's income annually. This sum is slightly larger, per student, than the grant the University provides to chemistry for each Part I student. It may seem a substantial sum, but the money is not channelled directly into the research groups. Instead, it is principally used to help meet the general costs of salaries and departmental resources such as libraries and computers. In other words, it helps support the "well-found" laboratory.

A small portion of the grant does arrive in cost centres for individual groups, but the expenditure incurred by Part II students is usually greater than this, and some support must therefore be provided from supervisors' grant income. This can limit the number of Part II students which a group can afford, but Part II students are valuable, enthusiastic and skilled "low-cost" labour, which most research groups are delighted to have access to.

7 What is the format of a project?

Part II has much in common with an MSc by research, and the way in which projects develop is similar.

During the first few weeks, students attend talks on the unfamiliar world of research. There are introductory and safety talks, and all students go on a first aid course. Courses in laser safety, biological safety and the use of radiochemicals and ionising radiation are taken by those whose research relates to these areas. In addition, specialised courses in computing, electronics and scientific glassblowing are offered.

This mix provides the grounding in safety and skills which students will need during the ensuing months, although gaps remain:

> "What about more applied courses like Science Communication...?"

[This comment, from a current Part II, is more perceptive than it may seem. Most students in the early part of their project will not realise the huge challenge which writing a thesis provides. Although the possibility of providing such a course has been discussed, no courses in scientific communication are currently offered.]

Once this introductory period is over, the efforts of the student can be devoted entirely to research.

Because of the length of Part II, students can make a thorough search of the literature, to place their project in a wider context. It is standard practice to provide students with copies of relevant papers to read during the vacation immediately preceding Part II, so that the project can get off to a rapid start.

There are more than one hundred libraries at Oxford, from the main University libraries to College and departmental libraries. The central University library, the Bodleian, is a "library of legal deposit", that is, a library to which a copy of every publication - of any sort - in Britain must by law be provided automatically. This has helped create a library of remarkable richness and breadth, which expands at the rate of well over one thousand items per day. (The collection is not only deep but esoteric; for example, the Bodleian contains the largest collection of bus tickets in the world.)

The library cannot afford to buy everything which it does not receive free, so the scientific holdings are not all-encompassing, but nevertheless match those of some of the best libraries in the world. There is thus every opportunity for students to delve deeply into the background of their project. At the conclusion of the project the examiners expect to see evidence that the student appreciates the significance of the research and can place it in an international context.

8 What kind of thesis is required?

In determining the final class of degree, much rests on the quality of the thesis, a point of which students are very aware. This has lead to something of a thesis "arms race", in which every technological advance in document presentation has been seized upon by students to make their work stand out from the crowd. Scanning past theses, one can trace accurately the arrival of word processors, graphics software, dot matrix printers, laser printers, colour inkjet printers, colour laser printers and so on. However, while students recognise that presentation is important, they also know that it is the quality of the research which really matters.

Theses resemble extended scientific papers. There is a limit of sixty pages on the body of the thesis to prevent students from being unnecessarily wordy (though appendices, references, computer listings and other material often boost the total to well over one hundred pages). Supervisors monitor the preparation of the thesis, but the ultimate responsibility for all aspects of it rests with the student, and this can place a premium on clear expression and grammatically correct work.

Through publications such as the Oxford English Dictionary, Oxford has gained a reputation as a place in which standards of written English are high. The truth is that, while our students are often accomplished chemists, they are not necessarily accomplished writers. Every year a few supervisors have a nasty shock when they read the first draft of a Part II thesis from one of their group. The preparation of a clear and persuasive thesis is one of the most daunting tasks in Part II, especially for those students who excel at science, but not at English. Writing is spread over a period of at least three months by most students. During this time there is often a perceptible improvement in the quality of their written expression, and this practice in writing English is an important benefit of the project.

A minimum of three copies of the thesis are prepared. Two are submitted to the examiners and one retained by the student for use in the oral examination.

9 Examinations

All students face an oral examination at the end of the year. Prior to this, the thesis is read by two or three examiners. The principle purposes of the oral are the same as the *viva voce* for a Ph.D. or MSc: to determine that the student who is offering the thesis is actually responsible for the work, and to clarify points of confusion or contention. Students may approach the oral in some trepidation, but once they realise that they are - quite literally - the world expert in one (albeit very small) area of scientific research, the oral generally proceeds smoothly, and students emerge from it relieved, even exhilarated by the experience.

10 Advantages of the Part II year for the student

The central theme of this paper is an attempt to answer the question "Is Part II worth it?" The next four sections consider the advantages and disadvantages of Part II, from the viewpoint of both student and department.

Part II forms a central plank of the teaching at Oxford, so it must be perceived (at least by the chemistry faculty!) as offering significant advantages. Let us consider now how students gain from the year.

10.1 Most students find that Part II is more fulfilling and exciting than the three years of purely academic work which precede it

Even the most committed chemists may find that three years of lectures, classes and practicals eventually begins to dull the appetite for chemistry. The desire to be a creator, not a consumer of knowledge begins to grow (or maybe the desire to learn just withers!), and as interests begin to focus on particular areas of chemistry, Part II provides the chance to specialise in the areas students find most intriguing.

> "You don't really know anything about synthetic organic chemistry until you do it with your own hands."

[which comment makes one wonder what this student was doing through the three years of organic labs in Part I!]

The sense of excitement which discovery provides can be considerable. After a while faculty who have published original research during their career may forget how exciting it was to see one's first paper in print, but to students starting out on research, the thought that their work will appear in international scientific journals and may influence the work of other research groups around the world is a great motivating factor.

10.2 Part II provides an insight into how scientific research is carried out

Many students will eventually pursue a career in research, in an academic or industrial environment. Research is a very different activity from learning through lectures and tutorials. During Part I students collate, learn and then regurgitate information, but Part II is a real contrast. The development of completely fresh knowledge is an entirely new process to most students, and the only way in which they can really appreciate how this happens is to engage in it.

> "It gives a good indication of what it is like to be a practicing chemist."

10.3 Part II offers the chance to experience academic research at first hand

Oxford produces more recruits for merchant banks and stockbrokers than any other chemistry department in the country. This is a source of regret for many of us, who would like to see more of our graduates remain in science. Nevertheless, despite the high salaries in London, the most common destination for our students is graduate research, at Oxford or elsewhere. The future health of scientific research depends upon high quality students being prepared to pass up inflated salaries in financial careers in favour of the less financially rewarding (but perhaps more satisfying) world of academic research.

By having the chance, through undergraduate projects, to taste academic life and research, and discover the satisfaction it can offer, students are able to judge for themselves whether a further degree, and perhaps a career in research, is appropriate for them.

Of course, for some the research remains secondary:

> "This year, because the work is less isolating, the social side of being a chemist becomes apparent. This is great!"

10.4 Projects promote the development of a range of research-oriented skills

Part II provides the chance to develop and extend a range of technical skills. Whether students concentrate on computing, synthesis, vacuum techniques, ultra-clean work or handling radiochemicals, these skills provide a useful grounding for anyone contemplating a future scientific career. For those Part II students who proceed into graduate research, the skills learnt during Part I can help them to make a rapid start to their second degree.

> "It really gives a flavour of what research might be like ... and develops skills in areas as diverse as electronics, physics, engineering/design and computation."

Furthermore, even those students who move into accountancy, consultancy, law or other professions outside science have the chance to develop skills in statistics, computing, communication and other areas which are likely to be of value.

> "It is also good preparation for having a job in the big wide world."

10.5 Students are encouraged to develop self-discipline and self motivation

Research does not make progress of its own accord. If students do not have the self-discipline to work hard at their project, no amount of persuasion or cajoling by the supervisor will force them to do so. Part II thus provides the chance for students to find out for themselves the extent to which their own efforts can keep them going during an extended period of work. Such self-motivation is of course important in all fields of work, not merely for those engaged in research.

The significance of this aspect of any undergraduate research project should not be underestimated. An important role of the Oxford tutorial system is to motivate the student. Once the research year starts, however, the student must rely very much on his or her own sense of discipline, and this requires real determination. Students learn a lot as they try to bring their project to a successful conclusion.

> "Whatever we need is done from our own initiative, and there is seldom anyone who checks what you say/calculate."

10.6 Students have the chance to develop presentation skills

Many Part II students give a seminar or presentation of their work during the year. They may speak infront of their colleagues at Oxford, or to workers at an industrial sponsor or collaborator. After three years of lectures students may have the (unwarranted!) view that giving a talk is easy; having to give one themselves can be a chastening yet valuable experience, and gives them the chance not just to experience speaking infront of an audience, but also to learn about the preparation of slides and other visual aids which they may need to enhance their talk.

10.7 Preparation of the thesis improves writing skills

Some people associate the tutorial system at Oxford with the preparation of long essays. In reality, most students in the sciences prepare few essays, and many will never write any substantial essay during Part I. The Part II thesis is the longest single item of writing any student will have embarked upon, and helps them to appreciate the importance of clarity, grammatical precision and style, important skills for when they move on to a permanent job.

11 Advantages of Part II for the department

Part II exists not solely for the benefit of the student. Indeed, it may be that the most significant advantages accrue to the chemistry department.

The department gains in two principle ways: enhanced research output and an increase in the attractiveness of the course to prospective students.

11.1 Increased research output

During a research project lasting just a few weeks it is hard for a student to do much more than add a few pieces to the large jigsaw of a long-term project. During an extended project, however, it is possible for the student to produce research which, on its own, should amount to one or two research papers in international journals. Clearly this adds considerably to the research effort of the department. Indeed, perhaps one paper in three emerging from the department arises partly or mainly from work carried out by Part IIs.

11.2 Enhancement of the attractiveness of the course

For most potential applicants, the year of research is a notable selling point for Oxford Chemistry. Many students view this part of the degree as one of the prime reasons to apply to Oxford, and there seems little doubt that this increases the size of the applicant pool from which Oxford can select. Inasmuch as this larger pool of applicants should lead to a higher quality of intake, which in the long term should lead to higher quality research, the Part II year enhances the research of the department both directly and indirectly.

> "The Part II year was one of the reasons I applied to Oxford, and I haven't been disappointed."

12 Disadvantages of Part II for the student

But Part II is not all sweetness and light - there are disadvantages too.

12.1 The degree may be seen by students as being too long

While four years is the typical length of a degree in North America, British degrees have until recently lasted only three. We regard the extra year of Part II as being integral to the course, and as having value on many grounds. Students (particularly those weighing up Oxford chemistry against a three-year course) do not always agree. They may see the extra year as unnecessarily delaying the time when they can leave University and start earning a wage. Worse, British Universities have recently introduced (or, more accurately, been required to introduce) tuition fees for all students. These fees put financial pressure on students to join the workforce as rapidly as possible.

12.2 A year-long project may offer too little variety

To students accustomed to lectures on several different topics each day, the sudden concentration on a single area of chemistry can be a bit of a shock. Even assuming that the student enjoys the work, the narrowing of focus may seem excessive, especially at times when the project seems to be making only modest progress (or none at all), and the student may start to wonder whether it is all worth while.

> "I would have preferred a scheme whereby I could work in two different labs, i.e. two six-month projects."

12.3 Students may have lost interest in chemistry before starting their project

The structure of the British School system is fundamentally different from that in North America. Students in their final two years at High School specialise in a quite narrow range of subjects. Most of our students concentrate on chemistry, maths, and either physics or biology during their last two years at High School, with relatively minor contributions from other areas of the curriculum. The decision to study science at University, therefore, is not made when students are actually at University, but perhaps as much as two years before leaving school, possibly for rather flimsy reasons.

> "The reason most people (my age) chose to do chemistry was because they liked setting fire to things."

As a consequence, we see a small number of students who decide at an early stage in the University course that chemistry is not for them. Most complete the degree, but in Part II turn to computing or History as a way to slip out of mainstream chemistry. Some will benefit from the additional breadth that this change of direction provides, but for a few the year of research is more an irritating delay before their release into the non-chemical world than a chance to do some innovative research.

12.4 Students may lack the skills necessary to write a lucid thesis

The overall academic quality of the intake at Oxford is high. Nevertheless, students are not equally proficient in all subjects. Some scientifically gifted students may have modest skills in written English, and to them the preparation of a long thesis presents a substantial and perhaps disagreeable challenge.

12.5 Students may feel the training of Part I is rendered largely irrelevant by Part II

Students may be taken aback to discover that the lessons learnt in Part I may not apply in Part II:

> "We have a year where all the skills of multitasking ... learnt in the first three years are diminished; the greatest virtue appears to be patience."
>
> "I miss the rigour of tutorials and the theoretical knowledge that was gained through our lecture program."
>
> "This year the broader chemical knowledge so painfully gained just seems to seep away."

13 Disadvantages of Part II for the department

Part II is also not without disadvantages for the department.

13.1 Organisational overhead

A significant effort must be made by the chemistry sub-departments to administer Part II. The organisation and presentation of Open Days, the allocation of students to research groups, and the monitoring and examining of projects all require considerable resources.

The examination process, for example, requires virtually full-time involvement of six faculty members for around a month each year. It is a measure of the regard in which Part II is held by the department that such commitments are accepted as being reasonable, set against the payback which Part II provides.

13.2 Requirement to train students absorbs time and resources

Most students need training before they become fully productive members of research groups.

"The way I thought the knowledge of the past three years would be applied this year just hasn't happened - my ability to do PES calculations for example is made completely redundant by the use of computational based results analysis."

Learning how to glass-blow vacuum lines, operate an X-ray spectrometer, or write efficient computer programs requires time, effort and instruction. In many groups day-to-day supervision of students is devolved to postdoctoral fellows or DPhil students, but whoever is responsible for the training, time is required which otherwise might have been devoted to research. Usually this time is more than repaid once the student is sufficiently accomplished to work independently, but at the early stages of Part II (and for some students, throughout Part II) the time required for supervision may be significant.

13.3 Poor students add little to the research effort

Not every student is keen, motivated or positive. In every year there are a few students who are less than enthusiastic chemists, and yet sufficiently reluctant to leave Oxford that they stay on to do Part II when they would be better advised to go elsewhere. Such students may not just contribute little to a research group - they may be counterproductive, consuming time and resources which would be better used by other members of the group, while not making the effort to contribute to the overall research effort.

14 Enthuse or Defuse?

So - does Part II enthuse or defuse? It's no contest. Overwhelmingly, students approve of Part II despite (or perhaps because of) the challenges it brings.

"I LOVE it ... personally the last two years have been the best at Oxford."

"Fantastic; it's great to get back to actually doing chemistry."

The enthusiasm which most have when they arrive at University, and which may have been dimmed by three years of academic work, is often rekindled by the project.

"The best thing I can say about Part II is that is has resurrected my interest in chemistry, and now I'm carrying on to do a DPhil."

The sense of doing something interesting and useful brings real meaning to the work, and the feeling of belonging to a proper research group is vital in making students appreciate the importance of their work.

The drawbacks and challenges of such a long period of research are real enough, and for a minority of students (and their supervisors) make the year a disappointment. For the great majority, though, this year is the highlight of their degree at Oxford.

"The 4th year is great, in that you actually get to do proper chemistry, preferably in an area you enjoy."

So what factors contribute most to the success of Part II? Firstly, the knowledge that one has a significant, substantial, personal and challenging project on which to work seems crucial. Students rarely feel they are just minions, at the beck-and-call of more senior group members, working on some obscure slice of chemistry in which they have no interest. There is the chance to complete a piece of research of genuine importance during the year, and this "personal ownership" of the project is vital.

Students appreciate the chance to chose their own area of research. This is not the case in every institution which offers undergraduate research; a variety of allocation schemes exist. In one well-known University, students are ranked according to their marks in the written exams, and the choice of supervisor then starts with the student at the top of the class list and proceeds in order down to the student at the bottom. This may provide an incentive for the better students to do well in the exams, but the impact on students near the bottom must, one imagines, be quite negative.

It is also important that the student feels that he or she has truly become one of the research community. This is fostered by the full-time nature of the work, and the fact that work is done in group research facilities, not, for example, in a teaching laboratory, where the student might feel the project is more an extension of the undergraduate practical course.

Overall, Part II has survived because it works, both for students and the department. The system is not perfect, nor does it suit everyone, but the long-term research project is a form of chemistry teaching in which the gains for both students and University are considerable. We would have abandoned the research year at Oxford long ago if we felt it did not benefit both students and University; its survival is testimony to the key role such extended projects can play as part of a student degree.

Appendix A. Some recent Part II project titles

Area	Title	Author	Supervisor
Computational / Theoretical			
	Genetic Algorithms	A.L.Tuson	H.M.Cartwright
	Synthesis Optimization	A.M.S.Cookson	H.M.Cartwright

A theoretical study of hole dynamics in finite-dimensional insulators	D.M.Buller	D.E.Logan
Hole dynamics in insulators: A Theoretical Study	N.L.Dickens	D.E.Logan
Neural networks for interpretation of infrared data	A.Porter	H.M.Cartwright
Structure-biodegradabiltiy relationships using self-ordering maps	J.Saunders	H.M.Cartwright
Nucleation and Growth Processes in Irradiated NaCl	R.Thomson	P.J.Grout
Simulation of Impurities in alpha-iron	R.Storah	P.J.Grout
Heats of Transport in Metals	T.White	P.J.Grout
Homology Modelling of Interleukin-2d2	R.Coventry	W.G.Richards
Advances in Electrochemical Simulations	B.Brookes	R.G.Compton
The Structure and Function of Hammerhead Ribozome	A.Sime	W.G.Richards

Organic

Enantioselective Rearrangements of Epoxides	M.L.Jones	D.Hodgson
Applications of Vinyldisilane Chemistry	S.F.Barker	D.Hodgson
New inhibitors of thrombin	M.Ragett	C.J.Schofield
Studies on Anthocyanidin Synthase	J.Turnbull	C.J.Schofield
Synthesis of Metallo beta-Lactamase inhibitors	N.Thaker	C.J.Schofield

Radical Cascade Methods for Synthesis	S.Roseblade	J.Robertson
Silicon tethered type I ene cyclisations	C.Ringrose	J.Robertson
Studies on the Synthesis of Roseophilin	J.Peverley	J.Robertson
Radical Cyclisations in Synthesis	H.W.Lam	J.Robertson
Synthesis of O-glycan Oligosaccharides	P.Dodd	A.J.Fairbanks
New Inhibitors of thrombin	M.Ragett	C.Schofield
Studies on Anthocyanidin Synthase	J.Turnbull	C.Schofield
Synthesis of Metallo beta-lactamase Inhibitors	N.Thaker	C.Schofield
Synthesis of UV-labelled Disaccharides as Tools for the Investigation of Enzyme kinetics	I.Cumpstey	A.J.Fairbanks
Studies in Anomeric Activation	C.Goff	A.J.Fairbanks

Physical

Development of a cell for the measurement of surfactant adsorption kinetics	J. A. Warner	C.D.Bain
Phase Transitions in Monolayers at the solid-liquid interface	C. McKenna	C.D.Bain
Sum-frequency spectroscopy at the solid-solid interface	G.Butterworth	C.D.Bain
Sum-frequency spectroscopy of surfactants and lipids at aqueous interfaces	D. Schofield	C.D.Bain

Spin polarised free radicals	A.M.Rothery	K.McLauchlan
Photo-CIDNP of Amino acids and Proteins	M. Cemazar	P.J.Hore
Electron spin echo spectroscopy in radical pairs	I.Sheldon	P.J.Hore
Chemical effects of oscillating magnetic fields	A.Curtis	P.J.Hore
Ultrasonic Enhancement of Electrode Processes	J.Hardcastle	R.G.Compton
Photoelectroanalysis	K.Woodhouse	R.G.Compton
Electroanalysis at the Liquid-Liquid Interface	A.Blythe	R.G.Compton
Theory of Electrode Reaction Mechanisms	P.Morland	R.G.Compton
Laboratory studies of the Night-time Chemistry of the Troposphere	K.C.Thompson	R.P.Wayne
Discharge-flow Studies of some Halogenated Species of Atmospheric Importance	M.Flugge	R.P.Wayne
Kinetic Studies of some Halogenated Atmospheric Species	A.J.B.Thomson	R.P.Wayne

Inorganic

The Inorganic Chemistry of Carbon Nanotubes	S.Bailey	M.J.Green
Transition Metal Adducts with the Strong Lewis Acid B(C6F5)3	B.Coapes	M.J.Green
Structure and Reactivity Relationships in Ansa-Metallocenes of Molybdenum	S.Turberville	M.J.Green

and Tungsten		
New microporous uranium-containing materials	J.S.Bee	D.O'Hare
New Selective Ion-exchange Intercallation Chemistry	V.Green	D.O'Hare
Organometallic-functionalised Mesoporous Silicates	M.Rowe	D.O'Hare
Studies of some Matrix Reactions of the Group 12 Metal Atoms	M.Long	Tony Downs
Structure and Dynamics of Molecular Crystals	P.C.Tan	S.J.Heyes
Studies of Inclusion Compounds using Solid State NMR Spectroscopy	S.Mahey	S.J.Heyes
Molecular Compounds Featuring a Bond Between a Group 13 and a Group 15 Element	C.Y.Tang	Tony Downs
Studies of compounds with an unsaturated hydrocarbon coordinated to a metal carbonyl fragment	J.Harvey	Tony Downs
Some methyl derivatives of early transition metals	N.S.Munkman	Tony Downs
Bandgap-engineered Phosphors for OLP-based OLED Displays	C.E.Foulkes	V.Christou
Organometallic Block Copolymers	H.L.Anderson	V.Christou
Photoelectron spectroscopy and Electronic Structure of Inorganic Molecules	J.M.Timberlake	V.Christou
Aspects of Luminescent Organolanthanide Materials	B.G.Hughes	V.Christou

Other areas

The Corrosion Behaviour of Steel in High-alumina Cements	I.Mills	J.Sykes
Pitting Corrosion of Stainless Steel	C.Green	J.Sykes
Investigations into the Oxidative Folding of Human Lysozyme	R.Wain	C.M.Dobson
Mutational Studies of Protein Folding and Aggregation	P.White	C.M.Dobson
Peptide Models for Nascent Chain Protein Folding	I.Schofield	C.M.Dobson
The Role of William Odling in the Development of the Theory of Types	J.Bourne	A.Chapman
Research and Production in the French Artificial Dyestuffs Industry, 1856-80	J.Corp	R.Fox
An Historical Account of the Development of the Benzodiazepines and Related Compounds, 1950-85	H.Li	A.Chapman
The use of Pharmaceutical Chemistry with Particular Reference to Teaching and Practice in Oxford from 1790 to 1900	A.Simmons	A.Chapman