Aligning Teaching and Research Strategies for a Distinctive Chemistry Curriculum: Final Report

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Abstract

This report follows on from research into the documentation and online representation of the department by the IATL (then Reinvention Centre) report prepared in collaboration with Kings College: *The Graduate Pledge*.[1] The report seeks to determine what students are offered in their first interactions with the Department of Chemistry and what provisions are made for their learning whilst at Warwick. We then go on to discuss with students and academics the role of research in undergraduate life and learning, whether this interface between teaching and research can be further developed, and what methods have been used to integrate these areas in other departments around the globe. We close with discussion of the challenges and opportunities facing undergraduates in the department, as well as their aspirations and some speculation as to how these might be best served.

> "The mind is not a vessel to be filled, but a fire to be kindled." (Plutarch, c46–127 AD)

Introduction

Aims and Objectives

At the start of 2011 it was announced that government funding for universities would be heavily reduced and to fill the funding gap created, student tuition fees would increase to up to £9,000 a year.[2, 3] Fees would not be paid up front, but would be made available in the form of a loan repayable after graduation. This decision was made as a result of the report created by an independent panel review, requested by the previous government as a cross-party effort entitled *Securing A Sustainable Future for Higher Education*,[4] generated by Lord Brown of Madingley and colleagues. They suggested a method to increase the sustainability of the university system, reducing the financial load on the public purse. The load would be transferred to students, who are most likely to see the benefit of the higher education which they are paying for.

A summary of outcomes from *The Browne Report* are detailed below:[4]

- Full time students will pay no fees upfront. [...] The same upfront support for the costs of learning will be extended to part time students.
- No one has to pay back the loan unless they are earning above £21,000 per year. Payments are linked to income.
- Students with higher earnings after graduation will pay a real interest rate on the outstanding balance for the costs of learning and living. The interest rate will be equal to the Government's cost of borrowing (inflation plus 2.2%).
- Any loan amount that is not paid off after 30 years is written off by Government.

Graduates see a return over their lifetime of an average £100,000 over individuals with two or more A-levels (those students who meet the entry requirement for university study). Degrees enable individuals from low-income background to enter higher status jobs and graduates benefit from better job satisfaction and substantial health and social improvements.[4] As these are personal, rather than national, benefits; it is reasoned that the individual should be responsible for funding this opportunity.

The Browne report outlined not only a shift in the responsibility for funding university, but also a more informed decision for prospective students, including better careers services for schools and more transparent and logical advertising by universities; effectively improving the 'market power' of the student as a consumer. This view - debated both in and out of the House of Lords[5, 6] - leads to the concept of increased competition between universities for the incoming student body, encouraging universities to make the worth of their courses clearly visible.

Warwick University - as part of the Russell group of universities and consistently within the top ten UK university league tables, whether in university tables or specific tables for chemistry degrees - seeks to deliver the highest quality courses possible, which will increase in importance with fees rising to nearly three times their current level.[3] This project was funded by the Institute of Advanced Teaching and Learning in order to assess the delivery of the Department of Chemistry's courses and identify areas of development.

Brief and Background

The brief of the project was to assess the general opinion regarding the delivery of the undergraduate chemistry course, and all other Department of Chemistry undergraduate courses; along with all the prospective student advertising material. One highlighted goal was to identify areas in which the research ethic of the department could be more closely integrated into the undergraduate course; reducing the perceived gap between study and research.

The hypotheses under test were as follows:

- The Chemistry Department advertises its course based on its research status and it is this status that brings prospective students in to the department.
- Undergraduate students do not feel involved with the department's research culture until their MChem fourth year (where relevant).
- Undergraduate students do not engage well with lectures delivered in a traditional manner.
- Lecture material delivered in a self-guided or problem and enquiry based manner would engage students more successfully.
- Interest in current research is such that engagement with research would increase motivation and engagement with the core topic.
- The Department offers and supports involvement in industrial, global and research opportunities, but these are not extensively taken up by the students.

Education at the nexus of teaching and research has been a highly debated field, with the precise definitions of research and the methods for integration being extremely diverse. For the purpose of this report we will not be debating the academic benefit for the integration of research and teaching - this has been widely debated elsewhere.[7-10] The interests of this project lay in the opinions and the potential practical viability of various options.

In 1969, Massachusetts Institute of Technology (MIT) launched their Undergraduate Research Opportunities Program, the first of its kind, which has been used as a template for undergraduate research worldwide.[11] Following this ground breaking move by the US institution, the Boyer Commission published a report entitled; "*Reinventing Undergraduate Education*"[11] which critiqued the traditionalist methods of teaching and running a university, and suggested that the student should be treated as a 'scholar' within the university system. This report and the Higher Education Academy's documents; "*Developing Undergraduate Research and Enquiry*"[12] and "*Linking Teaching and Research in Disciplines and Departments*"[13] give a great deal of context, and a large collection of case studies for the origins and current efforts towards the integration of research into an undergraduate curriculum.

Attributes of students as scholars

Active critical thinking:

- Accepts responsibility for learning.
- Uses answers as an opportunity to ask more questions; is not constrained by the specific requirements of a course or project.
- Understands multiple perspectives.
- Has the ability to self-critique.

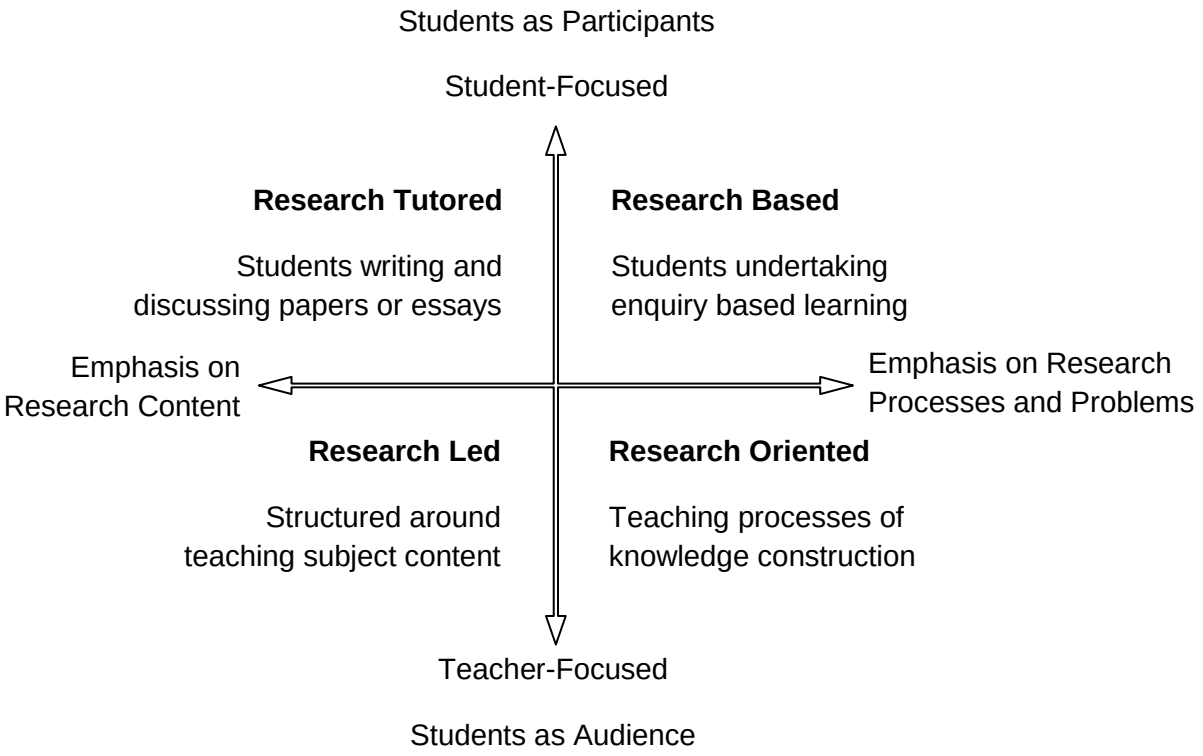
Research skills

- Lays out appropriate methodologies for scholarship generating or using original material.
- Understands how to work collaboratively, even in a geographically dispersed team.
- Integrates learning both within and across disciplines.

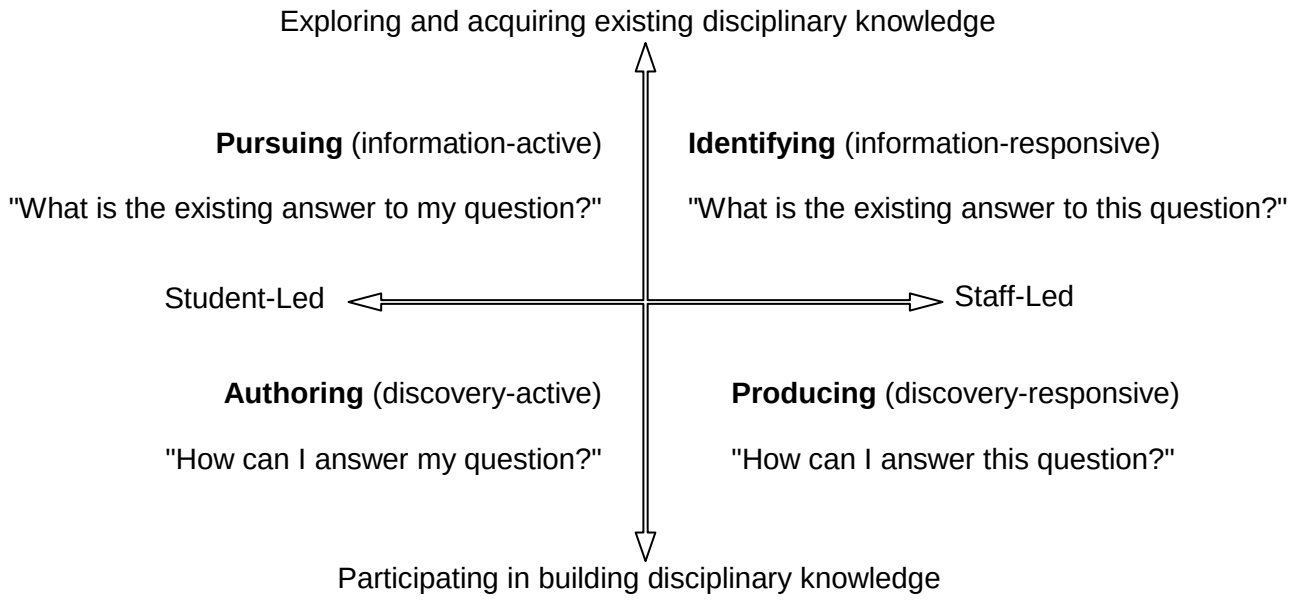
Self-authorship

- Is internally motivated, not needing external pressures (such as assessment or award) to initiate work.
- Believes he/she is capable of authoring new knowledge.
- Judges new information based on personal values and belief system, rather than relying on external authorities.
- Sees oneself as a member of a larger community of scholars, and looks to peers in order to share viewpoints and contribute to the quality of critical dialogue.

As a result of these developments and extensive further discussion in the literature, well defined structures describing the interface between teaching and research have been proposed by Healey *et al*[8] and Levy *et al*.[14] This ability to define research in a teaching context is vital to allow accurate and concise discussion of the options available.



Healey definition of the interface between teaching and research[8]



Levy definition of the interface between teaching and research[14]

Research skills include:

- Analysing a system.
- Reading around an area.
- Problem solving and experimental design.
- Using data-fitting or graphical representations.
- Communication of results.

As part of this project, opinions on the integration of the teaching and research aspects of the department - perceived to be highly separated - were collected. This integration is the primary option under investigation as a method of creating a more distinctive - and hence more appealing - undergraduate course for the prospective undergraduates of the future.

In the long term, the university benefits most from producing students who are highly employable, as the higher earning students will be those who most successfully pay off their loans with the accrued interest, and hence reflect well on the university in industry. The conclusions of the Confederation of British Industry (CBI) report *Future fit - Preparing Graduates for the World of Work*[15] is summarised as part of this report, and methods for moving towards these business-conceived goals are highlighted. However, as part of the House of Lords debate on the changes in Higher Education Funding, it was highlighted by Lord Bishop of

Wakefield that: "Implicit in the understanding of the European humanistic ideal of education was a continuing commitment to a liberal education. In the [Browne] report, there seems to be a largely unexamined premise that the primary role of universities is to prepare people for work and to serve the economy."[5]

Challenges To Teacher and Learner in Higher Education

There is a step identified in the literature between A-level and degree level education styles and motivation in the current generation which is well defined in a paper by Weiler (2005).[16] Between high school/college education and higher education, learning moves from dualistic knowledge (good or bad, right or wrong) to multiplicitous knowledge (there are multiple points of view and no one concrete answer is known by the whole, if there is one at all). In the dualistic stage students see teachers and other adults as authorities, and the information provided by them as either good or bad, creating either good authorities or bad authorities, depending on whether or not they agree or disagree with the teachers' information.[17]

Training students to move towards a concept of multiplicious knowledge without doubting the knowledge of their authorities is difficult. For this reason, getting students to understand that there is not always a consensus amongst academics can be jarring in the early stages of higher education. In the final stage of personal development the individual trusts their own authority, which allows intellectual debate and defense of belief.[17] It would be hoped that in training a researcher - whether academic or industrial - they could be brought to a position where they feel comfortable to defend their knowledge.

The way students perceive information changes in a fundamental way during this transition, and many of the things identified by academics as lacking in students (lack of scientific thinking, poor scientific discourse, and students being unwilling to challenge knowledge) may stem from a failure to guide this transition. In the same paper it is identified that "Students felt the search for common ground and consensus should always take precedence over disagreement or debate, regardless of [...] the possibility of new information to be learned."[16] This thinking might seriously hinder the training of a scientifically enquiring mind - which is built entirely on challenging views and defending a scientific standpoint.

Methodology

Types of Research; Their Aims and Biases

Focus Groups

Focus groups were used to answer complex questions which required explanation and discussion. These were mostly led and mediated by the undergraduate researchers, which allowed students to talk to peers. The outputs from this type of interaction might be expected to be more open, frank and honest than if students were talking to a module director, academic or postgraduate.

Focus groups were run for selected groups within the undergraduate body; first years, students who had visited Tasmania the previous academic year, students who had undertaken an industrial placement the year before, students who had undertaken a URSS placement and students undertaking a joint honours course. Several small focus groups were carried out at the end of the third year inorganic labs - a research-based lab, where a generic reaction scheme is repeated three (or four) times with the option for the students to modulate reaction conditions or reagents of their choice in the later stages to follow a 'story' in the research outputs. A focus group bringing together academics and undergraduates was also run in the final phase of the project.

Advertising was carried out with the use of Facebook© groups, University MassMail© emails and limited posters around the department. The focus groups were held either in the Library's Teaching Grid or in the Department's C521. Audio from focus groups was recorded, allowing the mediators to focus entirely on the flow of the discussion and a list of broad question prompts was used to focus each session.

The primary issue with the initial focus groups was attendance, which was attributed to the students having no emotional connection with the advertising material. The project was unknown to the students and initial promotional emails were sent out by the student researchers, which may have had a negative impact on attendance, due to a perceived lack of authority or importance. As a result the primary attendance was of close colleagues of the research panel.

In order to improve attendance email communications were sent though Prof. Peter Scott, raising the perceived importance of the research being undertaken. Considerations of the students

timetable was taken into more detailed account, aiming to catch the students in a period where they were between lectures but not in a position to go home. Additionally refreshments were offered.

A secondary issue with the focus groups was that the students often had issues which had arisen that they felt needed voicing, but didn't always fit with the theme of the focus group. It was possible that the strong opinions of a small number of members of the focus group could move the rest of the group away from voicing counter opinions or views on the original topic.

This issue could be controlled by careful moderation of the focus group and by making the aims of the focus group very clear from the outset. The benefit of using dictaphones to collect focus group outputs was also highlighted, as this allowed the subsequent summarising of salient points.

Interviews

Interviews were used to probe the answers to complex questions which required definition and explanation. Interviews were primarily carried out by the postgraduate researcher.

Due to the time constraints on academic staff it was more feasible to approach academics through one-on-one interviews. All academic staff listed on the *Academic Staff @ Warwick Chemistry* page[18] as Professor or Associate Professor were contacted and fifteen out of the twenty nine academics were interviewed, including the Head of Department. Additionally five members of the support staff were interviewed.

A broad spectrum of questions was prepared for these interviews, covering all areas within the project. The interview was allowed to proceed as naturally as possible, but was guided towards a couple of key questions in each area of interest. Interviews were steered depending on which academic was being interviewed and their area of responsibility in the department.

Questionnaires

Several different questionnaires were used to gather data during the project. As in the focus groups, advertisement of the general questionnaire was carried out with the use of Facebook©

groups and MassMail© emails. It was made clear to the students that the replies given would remain anonymous and that they would be processed by the undergraduate and postgraduate researchers, rather than academics in the department. This removal of academic observation allowed students to be open and frank with their replies.

An initial questionnaire was prepared to contact prospective students who were visiting a university-wide open day. Promotion for this questionnaire was through mini-posters handed out throughout the day with a brief introduction to the project. This questionnaire investigated the motivations driving their choice of university and their interest in research careers at that stage in their education. Return was poor for this questionnaire and so a very similar questionnaire was issued to the first year students. A greater than 10% return was achieved for the second questionnaire.

A larger questionnaire was designed to investigate the current opinion of students on the course across all four years, the students' interaction with the research culture of the department and the interest and uptake of extracurricular research opportunities. Return for this questionnaire was improved by follow up email and personal contact reminders.

This questionnaire was opened up to postgraduates in the department, both from Warwick and, in a separate questionnaire, students who had done their undergraduate in other universities. While return from this last questionnaire was poor, it allowed for a loose comparison between universities from the prospective of students who have already started their research career elsewhere.

Questionnaire on Choice of University	
Target group	Number of returns
Prospective students	3
1st Years on their experience as prospective students	31

Questionnaire on Research Topics			
Year Group	Questionnaire Return	Current Population*	% Return
1st Year	23	149	15
2nd Year	19	95	20
3rd Year	17	100	17
4th Year	12	57	21

* Population taken from personal tutor lists. Does not include biochemistry students.

Results

The Offer

When students approach choosing and applying for a university, there are several resources available to them.

The UCAS website offers advice on 'how to choose the right course' and 'choosing a university or college'. Links to an online Stamford Test allows students a chance to identify the courses they might be interest in, and a link to the website 'Unistats' (created by UCAS and Hotcourses Ltd.) allows comparison of UK universities and colleges by subjects available, average UCAS points on entry (rather than the published entry requirement), percentage of students employed in a graduate roll six months after graduation and percentage of students satisfied by their course upon reflection, after graduation.

Many students use the league tables published by the Guardian, the Times and the Complete Universities Guide; and for the world tables QS (Quacquarelli Symonds Limited); to determine the quality of a university and of the courses offered. The scoring offered by these tables are often taken without investigation into their creation or which of the ranking criteria are most heavily weighted.

Individual university websites are a rich resource for information regarding a university, a department and its courses. While a paper or digital prospectus can be downloaded or ordered

from the university website, much of the material is available on the departmental pages, and most students seem to access the information in this manner.

An open day is a chance for prospective students to see the university, talk directly to academics and current students and experience what student life is like. There are departmental and university-wide open days. During the departmental open day students receive an application pack which contains a departmental brochure, information on the courses available through the department and the careers service, ERASMUS opportunities, the language centre and university accommodation.

Documentation

The undergraduate handbook is linked on the department's page for prospective undergraduates. The handbook describes the department's excellence in teaching, world-class facilities, varied program of courses, RSC accreditation and lively and friendly department. A mention of keeping the course content current by using research and industrial links is included in the careers section. Key/transferable skills are defined as all being achieved by supervised and individual learning, rather than by teaching. This differentiation is potentially quite important. It is also stated that "[undergraduate students] will have the opportunity to undertake a piece of original work within a research group of your choice. Not only will you get hands-on experience of academic research working alongside postgraduates and postdoctoral fellows, but undergraduate projects often generate a publication in a chemistry journal." This is only true for MChem students, but could potentially be a big draw to the course.

The concept of 'personal scholarship' is emphasised in the individual pieces of documentation for all of the different degree stream options, introducing prospective students to the idea that students have to achieve their own learning and academic achievements in a degree setting.

Academic and industrial research are both highlighted in the four year MChem documentation, with the phrase 'qualified for a career in research', emphasising how the degree will prepare students for a range of employment opportunities.

The BSc documentation highlights industrial, teaching and service-sector careers opportunities, showing that this is the better option for those students not intending to go into industrial or academic research. However, the opportunity for students to prepare for a career in research is also highlighted.

The Chemical Biology documentation defines the course boundaries as the interface between chemistry and biology - in this manner the course can seen to be interdisciplinary (covering two areas in an integrated manner),[1] suggesting it will be more integrated and coherent. The three year Biomedical Chemistry degree has been named to appeal to students planning to undertake a postgraduate medical degree.

The Chemistry with Management degree is multidisciplinary,[1] with modules being taught by both the Chemistry Department and Warwick Business School (WBS). The course information suggests the course is for "those students who have already decided on a future career, not as a practicing chemist, but in management…". The quantity of practical chemistry is decreased in years two and three, obviously leading to a reduction in the practical lab skills of these students – relative to other non-multidisciplinary students. Interestingly, WBS isn't mentioned directly until the module list, despite the centre being prestigious and recognised worldwide.

The chemistry with medicinal chemistry degree is in part delivered by external lecturers from major pharmaceutical companies, keeping the content at the cutting edge of research, and also affording students the chance to interact with industrial chemists and understand industrial motivators.

The undergraduate brochure describes academics as 'world leading in their research' before it says they have 'great enthusiasm as teachers, mentors and personal advisors'. The laboratories are described as designed to 'current industrial practice' – hence exposing students to what they might expect in an industrial setting. The department's research culture is said to 'inform and inspire us and feed directly into our teaching'. The university's RAE scores and QAA assessment summaries are also mentioned.

Website

When the department of chemistry website is accessed the first page predominantly discusses research and international collaborations ongoing in the department. This may suggest to some that undergraduate teaching is secondary in the department to postgraduate research. Upon following the 'undergraduate study' link the area is divided into six sub-sections: the reputation of the university, including selected league table results and the RAE results for the department; investment into the department; the quality of the department; social aspects of the university and the improvements made to the undergraduate labs.

Publicly Available University Assessments

The university's performance in the delivery of higher education is assessed by the Quality Assurance Agency for Higher Education[19] (QAA), with the quality of research carried out in the university's departments being assessed by the Research Assessment Exercise[20] (RAE; soon to become the Research Excellence Framework[21]). Both of the most recent assessments are available online.

The QAA assessment is the most relevant to undergraduate students, despite the RAE assessment being the more advertised result. This may be due to the RAE result being more easily represented using simple statistics, whereas the QAA assessment is rather more verbose.

The Undergraduate Research Scholarship Scheme - URSS - was identified by QAA as a feature of good practice, getting undergraduates involved in research during the summer holidays as early as first year. As a method of developing research in the curriculum, there is funding available from the URSS, as well as the Reinvention Centre Small Grants Fund and Staff Fellowships from the IATL to 'develop the links between teaching and research'. The SSLC was also highlighted as a beneficial 'Student Representation Framework'. However, the management of joint honours degrees and the consistency of personal tutoring were highlighted as areas that need action.

The Department's courses are either RSC recognised (3 or 4 years bachelors) or accredited (4 or 5 years masters). This denotes conformance to the Chemistry Benchmark Statement,[22] which

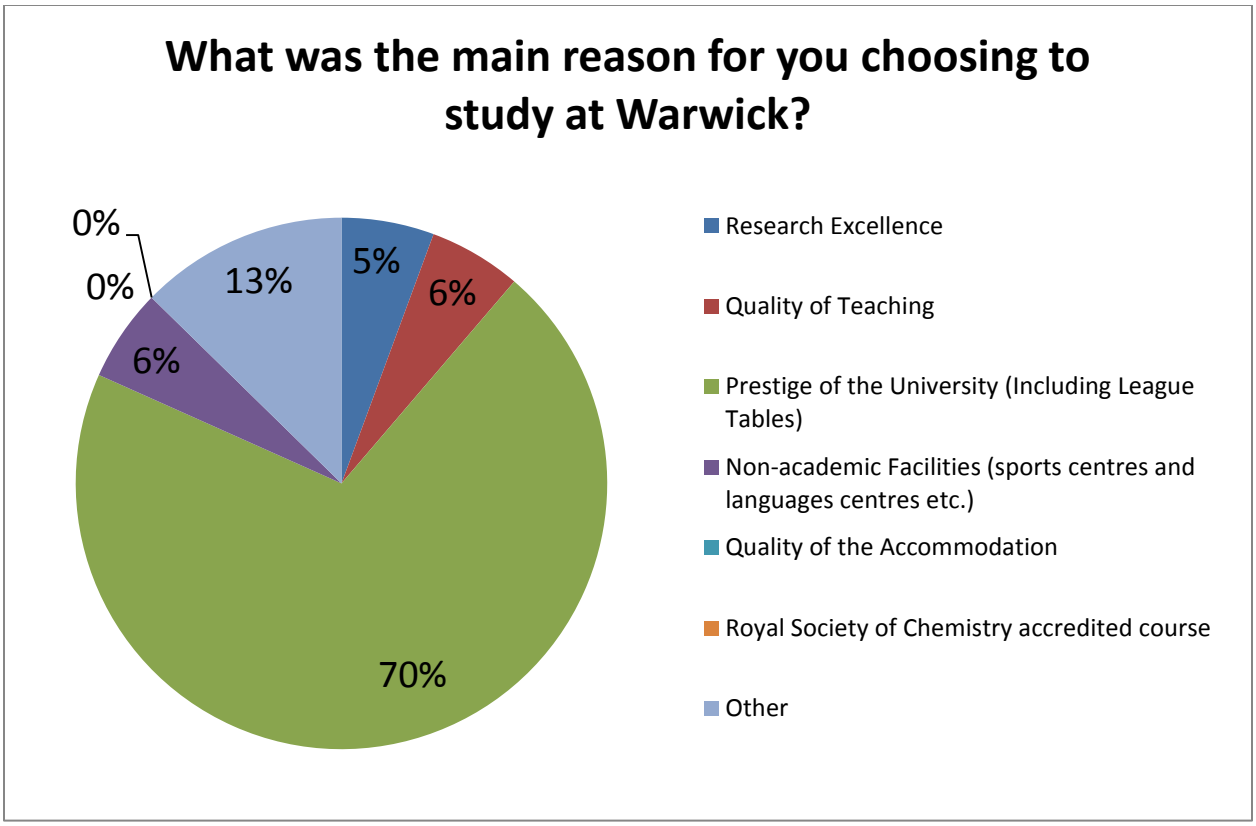
claims to assess output standards, not input measures - assessing how the student has learned, not how the material has been taught. However, it also gives guidelines on provision of teaching, support and assessment, which is perhaps contradictory to its goals. The Benchmark Statement is created based on collaboration between an academic and industrial panel and encourages a strong emphasis towards encouraging students to apply their knowledge of chemistry within a variety of problem solving contexts and with originality.

Questionnaire and Interview Results

Questionnaires were returned from a small number of prospective students who attended a Chemistry Department admissions day and by a proportion of first year students. Furthermore, a small group of first year students were interviewed on their experiences as prospective students.

Other than the University Prospectus, which is received separately from the other prospective student materials, the most remembered hand out was the Chemistry Undergraduate Brochure. It was mentioned by the focus group that the materials did little to differentiate Warwick from other universities and that the primary message was sometimes hard to determine. Results of the questionnaire indicate most students determined the message to be that the Department is a centre of research excellence, the quality of teaching is outstanding and that job prospects for Warwick graduates are great. 19 out of 25 responses to the first year directed questionnaire considered league tables 'important' or 'very important' when choosing a university. Choosing a university with good standing in league tables gave what one student defined as better 'bragging rights'. Almost all the students who responded to that questionnaire had considered a career in research after their degree (30 out of 31 responses - 97%) although only 74% of respondents felt they were informed about research careers by their college or school.

Interestingly, some students mentioned in the larger questionnaire that the course or department did not live up to their expectations compared with the way the course had been advertised to them on open days. The difficulty in the transition from A-level to higher education is often bypassed or sugarcoated in these discussions in order to encourage students into the Department. The contrast between school and undergraduate learning could maybe made clearer in these discussions to avoid this misunderstanding in future.



The Provision

The current undergraduate course features considerable provision for research integration with teaching which can be categorised by how it falls into Healey's structure as described above. The first two years consist of primarily the learning of foundation knowledge onto which the more complex concepts can be later built. In labs, the students learn the base skills which will be used throughout their career. Key skills sessions encourage students to improve communication and IT skills as well as group work. In the third year modules students are encouraged to follow up material on their own, and the nature of the lecture courses means that more independent learning and group work is required. This allows the students undertaking distance learning whilst on placement to follow the modules. Third year labs focus on students developing their ability to design experiments and solve problems using the skills developed in earlier years. This progression from academic guided learning into student guided learning allows students to prepare for the fourth year MChem project or work industry or academia after their third year. The fourth year is highly research orientated. Modules revolve around research ongoing in

academic groups and are connected to current literature. Students undergo a two term research project, the results of which are disseminated through a report, interview and presentation session.

During first and second year lectures, course materials are frequently contextualised by academics through the use of references to literature materials. These references are generally given in bibliography style, and so it is dependent on the student to have the ability and the willingness to find the original paper and to read it. Whilst all of the material learned during these years can be considered to fall into the research-led area - teaching subject content - the use of literature references facilitates students who have a desire to read around the area, and also demonstrates how the basic material fits into broader scientific context.

In year 1 and 2 labs, the basic skills taught are those which are used in research and industry. The student is an active participant in the learning, and it is their responsibility to read around the area before the start of the lab to ensure they understand the material they are preparing to do. The consolidation of this learning takes place through the repetition of base skills throughout the lab sessions; students have the resource of demonstrators throughout the lab period. Marking is completed primarily by demonstrators, and feedback is delivered either by email or as notes made in lab books following the lab report. The carousel system has complicated the system of feedback as the order of labs leads to the possibility of students discussing the results and marks from one lab, with students who have not yet undertaken the lab.

> "[Reading journal papers] is how I picked up how to write. I read hundreds of papers last year [in my industrial placement], and the more you read the more you get into the style of writing, the style of reporting results and the style of presenting tables."

Key skills covered in the first two years are those transferable skills which the student will use throughout their undergraduate career, as well as in research and industry after their degree. These include scientific writing, oral presentations to a range of audiences, molecular modeling and critical analysis of literature sources. These types of skills are improved through practice, and most are essential for students in all career paths; whether academic, industrial or elsewhere.

There are a variety of extracurricular options available to students to develop their confidence in the lab and to improve their communication skills and research skills during their undergraduate degree. These are industrial placements (industrial training), international exchange program (professional experience), the Undergraduate Research Scholarship Scheme (URSS) and other opportunities for funded undergraduate research. Industrial placements and exchange programs take place in the third year, and replace third year lab experience.

The industrial experience placements are a 6-12 month project in an industrial setting. Assessment is carried out by a written report, interview and oral presentation (with confidentiality agreements in place), as well as a report made by the industrial supervisor. The primary professional placement (6 month industrial placement or placement in an overseas university) is the international exchange run by the Department to the University of Tasmania. 6 month industrial placements are also available, but are highly competitive. The aim of these experiences is to give the student an opportunity to experience a research environment - either in industry or in academia. Professional placement students, for example, are asked to reflect on how their skills have been developed by their placements.

URSS and research projects are generally undertaken during summer holidays from first year onwards. They are highly guided during earlier years but the student is fully involved within the research group and is treated as a fellow researcher.

It is emphasised by the Confederation of British Industry (CBI) review[15] that for good employability, students need to engage with their department during their degree. Simply getting a degree is not enough in isolation. Learning for the purpose of passing exams does not benefit the student in the long run. The real world does not look at marks, but rather at skills and mindset. The exams are a means to an end and are there to assess understanding rather than the students' ability to cram and regurgitate material.

Module Documentation

Module documentation forms for all the modules that are taken by the students are posted online. Simplified and specific learning objectives are listed, along with the method of teaching and the

method of assessment. Whilst traditionally it might be expected that the learning objectives of any module are to know the required material, teaching to be done through lectures and assessment to be via exam; the Departmental objectives focus more on understanding and applying knowledge, with a variety of different teaching methods and assessment types. Based on the module documentation forms, the following are examples of innovative and non-didactic teaching methods already in use in the department.

First year labs are identified as training students to a 'professional standard' in the labs. This is said to include processing own data, improving manipulative skills and solving problems in the main branches of chemistry. The maths and physics for chemists module is delivered with extensive use of directed learning and alternative teaching methods (workshops, web and computer based tasks), and does not list lectures as a method of enabling students to achieve learning objectives.

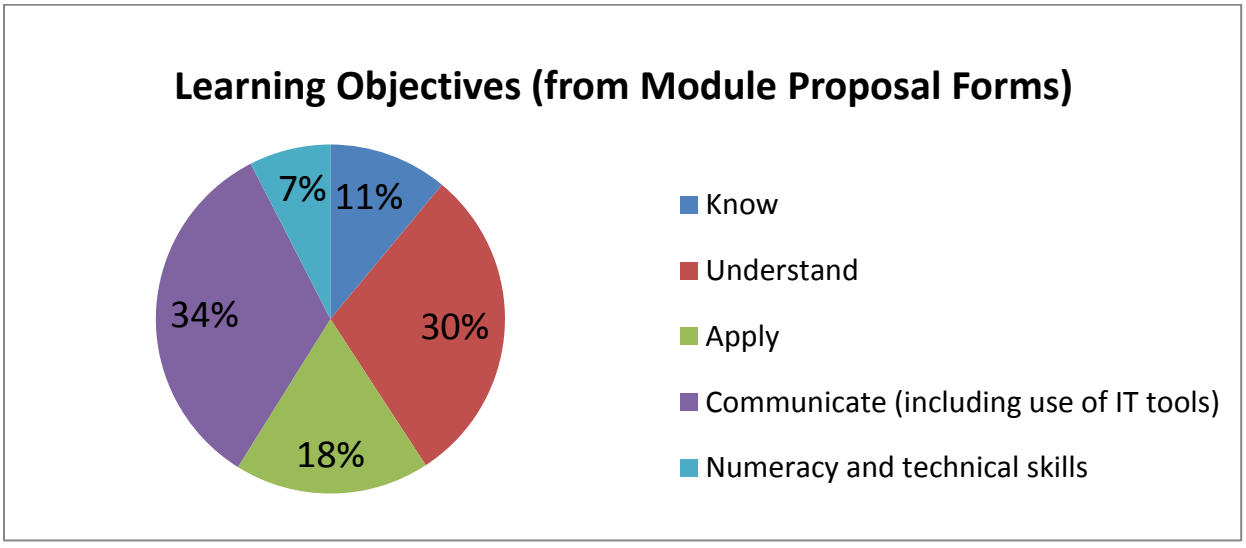
In year 2 the labs aim to give students 'confidence in planning experiments', and part of the assessment is identified as 'verbal discussion with a senior demonstrator as assessment of learning outcomes'. Feedback on the lab and lab reports is listed as a teaching and learning method, which makes feedback a very important part of the lab process. In the polymer module discussion with tutor is listed as an assessment method, and in the solid state module methods of teaching include guided reading. This is approaching a broader, less didactic method of learning. In addition, the organic module aims to "provide a framework in which students are able to critically evaluate material and design synthesis". It is implied that the student is working towards their own understanding, guided towards learning rather than taught. Third year quantum mechanics provides a tool kit for analysing chemical physics data - giving a problem solving context to the material learned.

Because of the distance learning aspect of the third year for those students who take on an industrial placement, the modules of the third year are designed to have more of an independent learning approach. Organic reactions and catalysis has lectures with 'presentations designed for self-paced delivery' with exams which are problem based with some fact-based element. This aims to improve students' transferable skills - team management, learning and development through self-study and appreciation and application of concepts to new situations.

Emphasis in third year labs is placed on experimental design and the evaluation and interpretation of original data. Safety aspects of lab work are more advanced in third year labs because associated hazards will vary considerably between one student's work and the next. Among the methods of teaching listed for the industrial placement is a guided review of previous reports to assist in the writing of the final report, and both mentoring and day to day direction are provided by the industrial supervisors. There is also external support from the student's personal tutor and module coordinator.

Introduction to Renewable Energy is an optional module which examines 'current and future energies, technologies and requirements'. This module can serve to contextualise some of the basic chemical knowledge the students have gained and connects important issues with broader economic, social and policy requirements. The Chemical Biology, Biomedical Chemistry and Chemistry with Medicinal Chemistry optional module 'Molecular Pharmacology' is delivered by representatives from major pharmaceutical companies and is entirely coursework assessed.

In the fourth year, the focus is on the research project; developing research skills and making the students aware of elements of research. The project allows students to be original in their application of knowledge to the solution of new, research-led problems. The aims of the fourth year modules are introducing an awareness of current problems and directions in the forefront of chemistry, and developing the ability to critically evaluate current research. During the fourth year, students are assessed by application of their knowledge to the solutions of novel, research-led problems.



Feedback from Academic Staff

Current Provision

Student Attitude Towards Learning

At school level, learning is principally task-oriented. The challenge for higher education is to create a self-learner - a student who will seek out information for their own gain. There is a temptation to spoon-feed students information because it is perceived that is what they expect. This produces poor graduates for the world of work or for research.

The material covered in the masters year modules is current and often up for debate in academia. This reminds students that Chemistry is not a dead subject, and gives undergraduates the opportunity to discover or rediscover material. Additionally, academics teach within their area of research and in some cases about their own research; as a result academics are often more enthusiastic. This enthusiasm is well received by the students and is often mirrored in their own resulting interest.

Key skills modules require students to produce essays, presentations and other audiovisual outputs, but these skills are not always specifically taught in the process. Chemistry specific skills are more directly taught within the department; molecular modelling and molecular visualisation software as well as database searching and literature searching. The key skills label in itself is a negative for students, representing something that was perceived to be hoop-jumping whilst at school and college. The year-on-year advancement of their own key skills set is not seen as a motivator, despite many later years' students admitting to having forgotten much of their first year key skills.

The Molecular Pharmacology module (available on the Chemical Biology and Chemistry with Medicinal Chemistry degree streams) encourages students to engage with the industrial outputs of academic research, and allows those students who are anticipating a career in the field a chance to talk to industrial chemists and discuss around areas which are current and fluid in molecular pharmacology.

Laboratory Learning

The new carousel lab system means that labs are not delivered in IOP (inorganic, organic, physical) labelled blocks, hence students benefit from observing the areas in which lab work crosses cluster boundaries. This encourages cross-modular thinking.

Labs are as much about the skills learnt as about the chemical made during the reaction. Students have the opportunity to take ownership of these results in the later years, as they pose their own questions and design experimental methods to answer them.

In the third year there are things intentionally left out of undergraduate scripts for students to discover or reinvent year on year. Third year labs are designed to mimic academic research. The inorganic lab gives students the opportunity to test their own hypothesis based on an experiment they become familiar with over a short period of time, physical chemistry prelab is presented by the student as a research proposal and the write-up for macro lab is written in the style of an academic paper. All of these skills contribute towards the students' ability to carry out their own research.

Dual or Joint Honours

There is a constant pressure to keep courses in-house to ease logistics and to aid communication with students. The boundaries between disciplines are artificial, and there are academics in all departments whose skills and research groups are such that they could be based in more than one department. This means a very broad skill set can be taught in a cohesive way - for example the joint honours Chemistry with Medicinal Chemistry.

Departments speak different languages, so splitting the course amongst departments - for example the joint honours Biomedical Chemistry or Chemistry with Management - require students who can be flexible in their learning.

Interdisciplinary courses are vocational courses, and so are often chosen by students who already have a good idea what area of chemistry they intend to be involved in when they graduate, but

they also lend themselves to increased flexibility for changing degree streams and breadth of knowledge for career choices after the degree.

However, in interdisciplinary degree streams fundamentals can sometimes be over-diluted by optional modules, especially in the case of joint honours degrees. This gap in knowledge means that some students enter later courses missing essential basic knowledge. This issue is almost impossible to resolve satisfactorily, beyond what is already in place i.e. prerequisite modules and background reading.

Opportunities not being taken up

The 'what do I need to know for the exam?' Mentality

If material is not to be examined or assessed, students will often not realise its importance or take the time to learn it - this includes *methods* for problem solving and answering those questions which are not likely to be in the exams, but might serve them in a research environment.

A clear distinction is made by academics between workshops and tutorials. Workshops entail questions designed such that the majority of students can answer them easily and academic support is provided to assist weaker students and to provide help in forming a structure for the problem solving method. Conversely, tutorials are designed with questions that students will find hard to answer. The much improved staff: student ratio allows staff to teach the more difficult material very intensively. Students are not being made aware of this distinction.

While academics make considerable effort to contextualise their lectures with optional references, students rarely engage with the extra material because of the ubiquitous 'what do I need to know for the exam' mentality. While some students return to use these materials during revision to support learning, this does not improve their breadth of knowledge, as was the original intent.

It is worth noting that students who are looking to go into research need the ability to seek out knowledge for themselves. While guiding students into research might benefit the key skills of

many students, by pushing research on students the act of seeking out research opportunities is not encouraged or rewarded.

The difficulty in training enquiring minds against the 'what do I need to know for the exam' mentality has been identified by many academics as a hurdle to overcome in the training of researchers. The motivation to enquire is based on excitement about a subject and where it can lead to.

> "We have to support [students], but if we have to motivate them they shouldn't be [pursuing a degree in Chemistry]. We have no responsibility to motivate the students. If they come to an environment like this and they're not motivated to do research and to learn, then they might as well just go."
>
> Mike Shipman, Head of Department

Support services

Students are offered the chance to hand in their MChem reports or introductions early for reviewing and feedback, but they rarely take up this opportunity until the last possible moment, giving the academic very little time to give useful, formative feedback.

The careers service offers a range of support services: from job applications to interviews; and also support the employability skills of students. This service is available to help and guide those students looking to help themselves. Pressing these services on students is not always in their best interests, but it is important that the student is made aware of what is available to them. Support for those students entering into a funded undergraduate research project, for example the URSS, is also provided by the careers service.

Areas missing

Communication Between Academics/Researchers and Students

Communication has been highlighted as a major problem on both sides. Students are not learning to a depth at which they can communicate fluently on a topic and this is hindering progression throughout their degree. Academics have also pointed out that often students aren't made aware of what is expected of them; the idea of self-learning isn't understood well in the student

community, and the concept of picking up transferable skills is not made appealing. Students aren't aware when they join the university what an investment they are making in the first two years towards understanding in the later years and into their postgraduate life. They are trained into the instant gratification culture where at the end of any academic year the knowledge they have forms a complete whole.

Students could benefit from earlier opportunities to engage, discuss and debate their learning. Early attempts at presentations, essay writing and scientific discussion will inform later attempts and help the students find improvements. Increasing the level of informal discussion between academics or postgraduates with students could improve their comfort with the concept of scientific thought, discourse, critique, insight, enquiry, innovation, creativity, their ability to make links between concepts and their willingness to learn things which are not going to be examined. The requirement of students to be able to read complex texts above their understanding and extract useful information from them, is of high value to learning at all stages.

Undergraduate level pitched research presentations - especially those covering method and approach to research questions - would be beneficial to get students engaged in research and how it takes place. Unfortunately, encouraging attendance to such events is always problematic.

The Department's social club - Atomic - has the potential to create a lot more involvement between years, for example student gatherings in an informal setting where undergraduates and postgraduates are encouraged to share experiences and skills. This could be a way of creating a scholarly environment to promote peer-to-peer contact and a way to develop scientific discussion skills.

‘Mentoring’ by PhD students or Postdocs who are interested in teaching later in their careers could be a way to foster communication between taught areas and research areas. This communication should be mutual - acknowledging that undergraduates have a breadth of knowledge where postgraduates have a great deal of specific knowledge. This moves students away from an exam question answering mode, and encourages real discourse. Spaces for discussion and developing scientific knowledge in an informal mediated setting, perhaps with a forum to organise specific revision or topic discussions would benefit students.

Key Skills

Scientific writing and literature research are skills not directly taught (along with efficient note taking, critical analysis and other skills expected to be taken from school level). These might be incorporated into key skills modules; however, unless the key skills modules are useful, they will not be attended. Material usually covered in key skills modules is already being incorporated into lab classes to teach and encourage practice of these skills in a more engaging context.

> "When we did key skills we said 'well this is a waste of time', but looking back now [in the fourth year] you can see what they were getting at."

> "If you made the endnote skills, the [scientific] writing skills an essential part of the lab write up, everyone would use them every week and everyone would be hot on them by the time they get to fourth year."

Earlier introduction of literature searching methods, poster presentations and scientific writing skills would give students more time to practice and improve these skills, but the learning objective has to be made clear. Every instance of practice will improve the skill itself, but for learning to occur the assignments have to be linked with other aspects of the students' work.

Appropriate reviewing and feedback on student material needs to be given if it is to be an efficient learning method - one-to-one feedback on essays and reports, in the style of that given by academics to Masters and PhD students during thesis writing is the most informative, but also the most time consuming.

Modular Boundaries

There is no assessment for students' abilities to think and connect concepts across modular boundaries. This leads to students not striving for these connections. Breaking down module boundaries is very difficult within the current system. Examinations or even tutorial/workshop questions with cross-module questions might encourage the ability to retrieve information in this way.

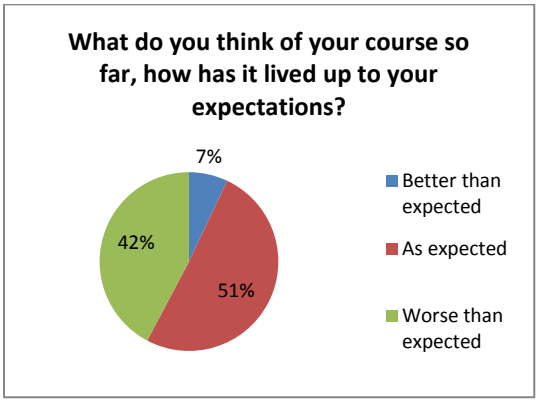
Maths and physics should be taught in a 'chemistry' style wherever possible, with a chemical context given by using SI units, real-life examples from a chemistry background and links to areas in which the maths will be used. Even if that area has not yet been taught, with the link already in place it will help recall of the required maths when that area of chemistry is introduced.

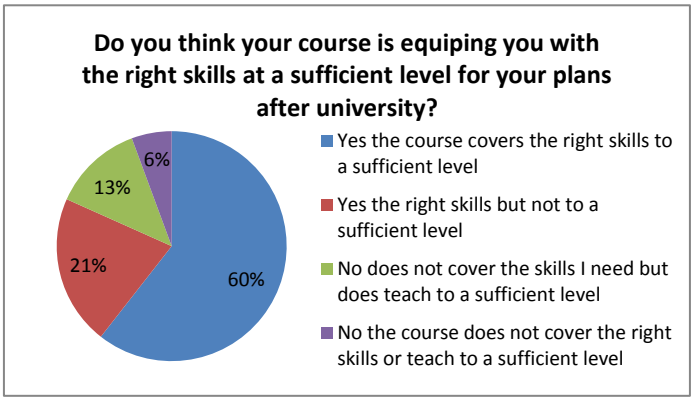
Something as simple as a list of practical skills picked up in each lab which could be checked off when a student feels competent at each one - without demonstrator assistance - might help students associate the lab work they are doing with practical skills they will need throughout their degree. This provides the student with a method for identifying their own development.

Feedback from Students

Current curriculum

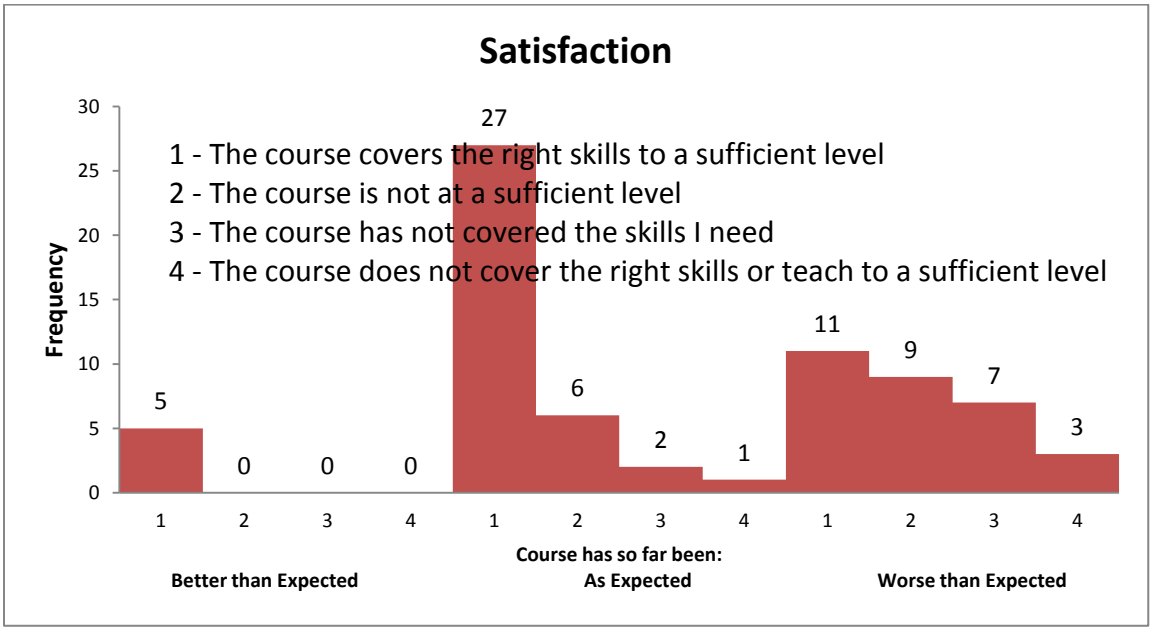
There was an interesting division returned in the questionnaire when we asked students first how the course had lived up to their expectations and then whether the course was providing them with what they felt to be the appropriate skills to an appropriate level. The results are shown graphically below:



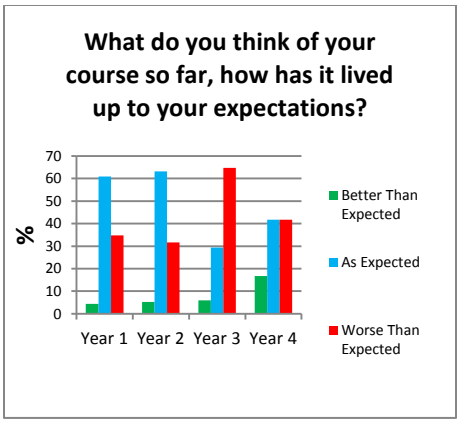


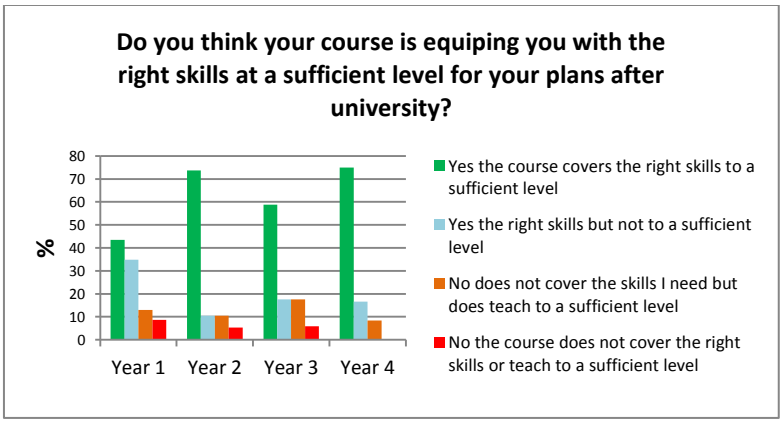
While a lot of students (42%) stated they were finding the course ‘worse than they expected’, many of those students (more than a third, see below) also claimed that they found the course to be providing the right skills, to an appropriate level for what they want to do post graduation. As

might be expected, the students who were finding the course better than they had expected were all happy with the skills and skill level provided. This suggests (and was confirmed when we requested that the students elaborate on their answer the question on expectations) that the issues the students are experiencing are not with course content but with delivery and pastoral care in the department. The most raised complaints were quality of teaching and attention and support from academic staff.

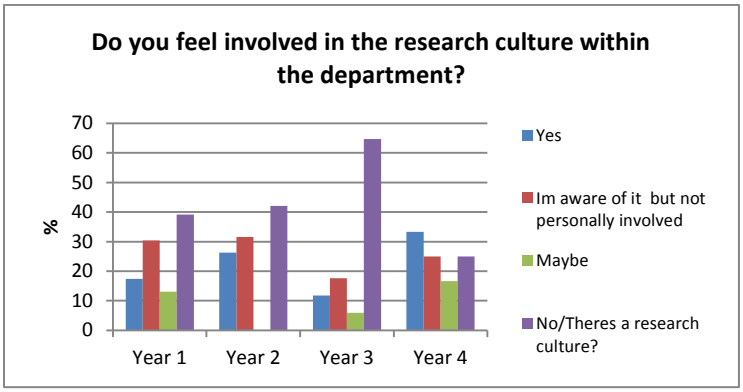


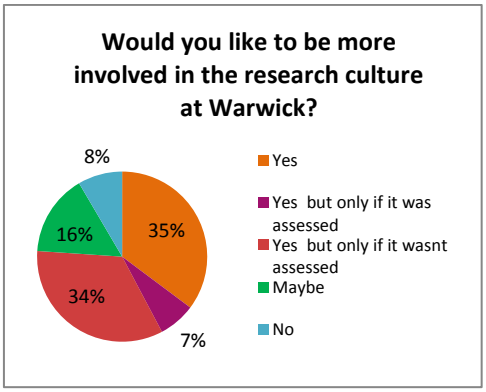
When these results were divided by year group (below), it can be seen that in the first year, as might be anticipated, the content of the course is not deemed to be at an appropriate level or breadth, but confidence in this aspect increases in the second year. The third year group has experienced a change in teaching at every year, a change which the second year cohort has consistently benefited from. This may explain why second year students appears to be more satisfied with the course on the whole, compared with students in the third year. Forth year students are experiencing research chemistry and it is reassuring to see that at this point we had no replies from students who felt they were not being taught the right skills to an appropriate level.





An initial aim of this project was to further integrate undergraduates into the research culture within the department. As a result we felt it poignant to ask students whether they felt involved with this aspect and would they would like to be more involved?





It was surprising to note that even in fourth year, where all students are actively involved in research within groups in the department, there are still a proportion of students who don't feel involved within the research culture of the department. This may be in part due to a lack of understanding of the meaning of ‘research culture’, and also an attitude within the department that separates undergraduates from postgraduates. Academics lecturing about research and updates on the Chemistry Department and ChemIntra website were identified by the questionnaire as the primary sources of connection which undergraduates have with research.

Students did voice a desire to be more involved in the research culture, though there was some debate as to whether that involvement should be assessed or non-assessed. Those students who voiced an opinion generally preferred the idea of non-assessed involvement, but a large proportion of students were interested regardless of assessment.

Students most successfully take ownership of their undergraduate lab output when the work feels challenging but is achievable. This level of difficulty will be perceived differently by all students and as such some students will always be dissatisfied. The disparity in the ability of students becomes less pronounced as they proceed through their degree. As a result, more challenging work in third and fourth year is of more benefit to the majority of students.

The research-styled third year labs are considered more interesting and more in line with a research ethos than labs in years one and two. After partaking in third year labs, many of the students interviewed said they would have been comfortable approaching second year labs in that style. However, there was a consensus that the first year labs need to be simple and easy to approach for those who hadn't experienced much lab work in schools, and for those who have taken a gap year.

The ability to seek out references and determine results through simple analysis is taught in the first year, and practicing these skills throughout the first and second year labs would be a good method of keep them fresh.

> "[The third year inorganic lab has] been repetitive, and at times frustrating, but I think that's what research is like."
>
> "It got a lot easier over the last couple of days, doing the experiments. I have to admit, we haven't been working in the labs for so long that I was really rusty on the first day I came in. It's easier now."
>
> "It [the Communicating Science module] was very interesting, but it wasn't very useful."

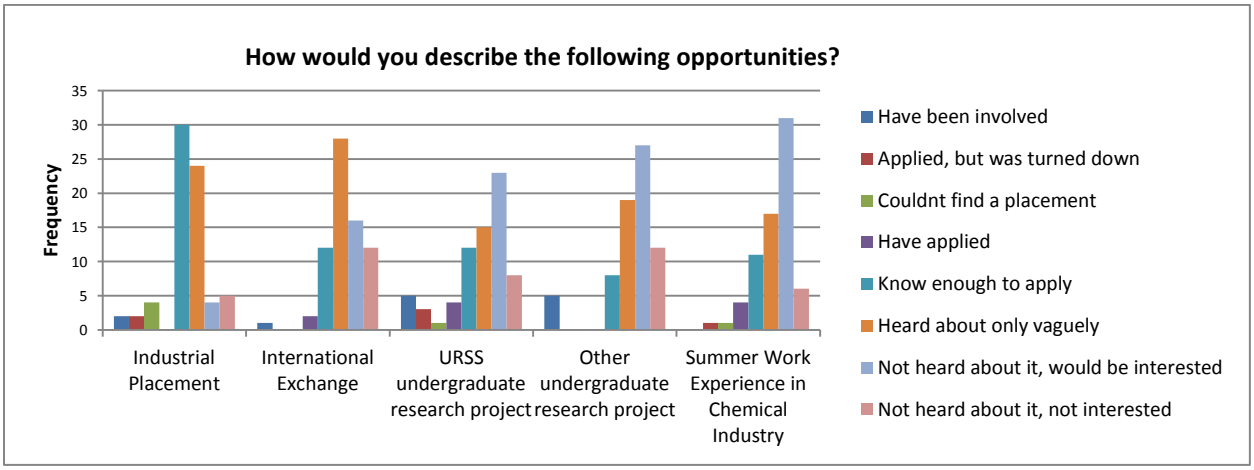
The Communicating Science module is available in the third year (taught as a joint module between the Physics and English departments) which covers techniques for communicating technical information to a variety of audiences. This is a very key skills heavy module with course work assessment. However, because every department 'speaks a different language' this is likely to teach skills which are not useful in a Chemistry context.

Students appreciate academics 'closing the loop' of feedback - summarising what has been said and responding to queries or issues raised in feedback - wherever possible.

Extracurricular Research Opportunities

There are methods for optional involvement with the research community throughout the undergraduate degree, even before the MChem begins - including industrial placements, professional experiences and the URSS. While URSS projects are often filled to the capacity of funding, other opportunities still seem to be poorly taken up, with many students admitting they had not heard about many of the options. While the industrial placement was seen to be well advertised, it was poorly taken up. This may be due to the highly competitive and perhaps intimidating application process. Additionally students voiced that they were 'comfortable' in the university environment, and breaking that comfort seemed like a stressful prospect. International exchange opportunities were not as well advertised and feedback from those students who have been involved suggests that the preparation for international exchange is notoriously difficult and often preparations take place during the exam period, further complicating the process. Undergraduate research opportunities in the department and in industry had the largest number of students who had been involved, but also the largest proportion of students who had not heard about them at all. Interestingly, these opportunities showed the highest number of students who would be interested should the opportunity be advertised to them, and are perhaps the least complicated to get involved in. This may suggest why advertisement is of a lower priority for these opportunities, as the most motivated and interested students will discover them for themselves.

It should be noted that not all opportunities were available to all of the students who responded to the questionnaire.



Where students have taken up extracurricular placement experiences, the support received by students from supervisors in their placement environments (URSS, Industrial and professional experience in Tasmania) has been highlighted as exceptional in all cases.

> "I can say I have benefited on the academic side of [the URSS project] and on the non-academic side. I took so many skills from what I did in my URSS project, I wouldn't have been able to carry on [with my MChem project] at the pace I've been going, in the way I'm doing it, if I hadn't done that year. I am independent, I'm not getting any support, I have been exposed to what exactly happens in reality so I'm not shocked. I cannot give it enough value."

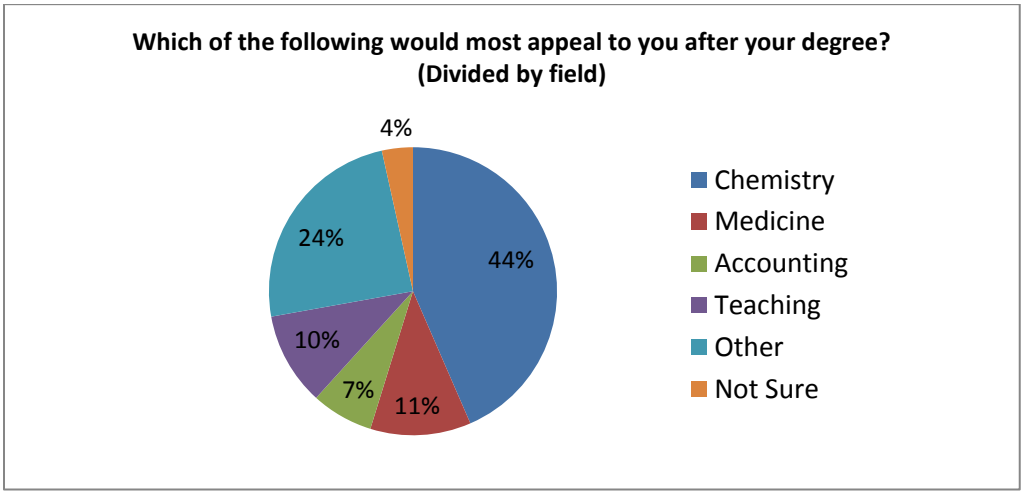
Students are aware of the RSC lectures and other lecture opportunities, but find that their time is limited, or they have already returned home by that time in the day, or even just that they have forgotten about the lecture. If the material in the RSC lecture is relevant or might aid in contextualising their current studies and was highlighted by a lecturer, this might encourage attendance. However, there was an opinion voiced that another hour of non-essential lectures is not reasonable on top of current workload. If this is a generally held opinion it seems impossible to imagine how we could get students involved in this kind of opportunity.

Students are aware of the references given throughout module lectures and some follow them up. References on graphs and tables allow students to learn how they were constructed and the practical research that went into constructing them. Material in references linked to the module content is generally used during the exam period to contextualise the revision and to give more material around the subject.

Opportunities and Ambitions

Those students who took on placements; whether industrial, as an exchange to Tasmania or as part of the URSS; were looking for an experience that they could compare to what they would find in industry or academic research. This gave them context for future job and academic applications. The students we spoke to would have been just as interested in something like the URSS if it were an unpaid opportunity.

While what students want to achieve out of their degree is highly diverse, a majority of students do want to stay in the sciences, whether in chemistry fields or medicinal applications of chemistry.



Areas Lacking

Students feel unsupported by tutors, or by course providers at Warwick (especially industrial placement students and Tasmania exchange students). The tutors need to know what they are expected to do, and they need to pass this information on to the tutees when they first meet, so that everyone knows what is expected. This would also be the ideal time for tutors to explain to students how the self-learning attitude at university differs from the spoon-feeding style of teaching at A-level, what level of work will be expected from them, and what level of support they can expect. Many students seem to expect school-level support when they should be working more independently.

Industrial students and Tasmania students need much more support from Warwick in the organisation of their placements. Communication between relevant academics, administrators and the final location is often poor, leading to students feeling abandoned. It has been emphasised that support by the host company or university is often exceptional. Final preparations often seem to fall during exam times. It is possible that students are not aware of how self-driven this process needs to be, and an introduction to this concept early in the first year followed by frequent reminders of the requirements may solve some of these problems.

Timetabling is a frequently raised issue, when speaking with students directly but also through the responses to the questionnaire. While students are generally aware that timetabling is highly complex, especially when it comes to the carousel lab system, that some students go into certain experiments with experience backed up by the modules and others do not have the same benefit is perceived as unfair. Equally, issues with highly divided days - with early morning lectures and late afternoon lectures - and lectures in lecture theatres which are an inappropriate size for the class leads to frustration for students.

As highlighted by the QAA report[19], communication between departments when it comes to joint or dual honours degrees is an issue. Modules which are optional in the earlier years for these students often contain foundation knowledge that make later modules more difficult to approach. Additionally, the lack of chemistry pigeon holes for students who are joint with biology, coupled with the fact that those students are not on the biology mailing lists means that information is not easily disseminated to those students. The Chemistry with Medicinal Chemistry students have voiced a desire for more foundations of biology modules made available in the earlier years.

CBI Report - Future Fit

The CBI report examined how universities were producing students for life in the workplace, and training them to be able to compete in the current job market. "Investing in employability during a downturn leads to success when pressures ease, but students need to engage [with their degree], and understand that getting a degree is not enough on its own."[15]

It is explained that it is important for students to understand that employability (more generally known as transferable) skills are not those taught by the careers service with the intention of getting a prospective employee through a CV/application check or an interview. Universities need to make it clear to students how the skills they are developing in the students are helping them prepare themselves for the world of work, beyond interviews and job applications.

Employability skills include: self-management, team work, business and customer awareness, problem solving, communication and literacy, application of numeracy, application of IT and a positive attitude. Entrepreneurship is a bonus, but one which is highly respected by business.

"A student who undertakes a placement or internship is immersed in the experience of being in a real workplace, allowing them to understand more quickly what skills they need and how to apply their learning."[15]

The integration of research and teaching

Literature suggests that undergraduate research should be original and cutting edge, suitable for publication. However, other sources define undergraduate research as students learning through courses which are designed to mimic research processes, such that the student is learning and being assessed in ways that parallel or mimic how research is assessed in that discipline. This division and the multiplicious definitions for research can be a barrier to finding common ground on which to explore the integration of research and teaching. Accreditation requirements encourage a practice called 'curriculum creep'[23]; where progressively, more and more material is incorporated into the curriculum. However, this technique restricts the time available for alternative teaching methods to be used in courses.

Despite these challenges, other institutions have established methods of integrating their research culture with their undergraduate population. A handful of case studies are described below, and immediate responses to these from our mixed focus group of undergraduates and academics are included. Further detail and case studies are available elsewhere[12-14, 24] - the HEA website is a highly valuable resource in this area. For logistical and implementation issues, the Handbook of Enquiry and Problem Based Learning is a good resource.[24]

One issue highlighted by both academics in interview and in the Handbook[24] is that undergraduate research requires a breakdown of the traditional power relations; a 'reengineering of the teacher-researcher nexus'.[25] Lectures are under the control of the academic. Problem and enquiry based learning is under the control of the student, who do not have a clear and coherent list of learning objectives or lecture notes. There is a fear that this will lead to incomplete or surface learning, and will not provide the required breadth or depth of study. While it should be noted that the most capable students will be doing their own enquiry based learning during the revision period to consolidate their learning, this is not led or encouraged by the academics, and no support is provided.

An additional block to the addition of any further introduction of research integrated, problem based or enquiry based learning to the undergraduate course is time and space; logistics. The introduction of a new module requires something in the course be removed to make room for it. A new module takes a large degree of effort to construct and must be both integrated and accessible. Modules with an enquiry or problem based structure require a lot of support; both for students, and academics.

Aspects covered well covered by Warwick

References to primary literature are used throughout all years of study, and departmental and cross-departmental research seminars are advertised and made available to all students.

Most modules contain tutorials and workshops which encourage problem based learning. Furthermore, some modules are constructed based on problem based assessment.

The third year lab sessions are based on research principles - literature searching, proposal, hypothesis forming, experimental design, COSHH, analysis and paper writing.

The predominantly research styled modules and lab work do not appear until the fourth year, meaning those students who do not intend to go into a chemistry career are not forced into developing skills which they do not feel they will need or benefit from. These research and problem-solving skills are essential for those looking to stay in chemistry, and so should be most incorporated into the final, optional MChem year of education, for those students who have made it clear that they intend to pursue a chemical career.

The department runs very successful URSS projects and other funded undergraduate research projects which teach high quality research skills from within a research group and are appreciated by the students involved. These projects are within real research areas and can contribute towards papers and authorship.

The department is very well respected for its students in industrial placement and international exchange situations.

Those lacking, and where they could be picked up

During the students' time in research groups in the fourth year, they have the opportunity to interact within research group meetings where their own knowledge is respected and considered by members of the group. This style of research discussion might be a useful aspect to bring into the third year labs where cooperation and collaboration are a large part of some of the lab structures.

The quality of demonstrators for undergraduate labs is variable, perhaps due to the fact they have minimal training in demonstrating and marking, but also because they are not themselves engaged or interested in the teaching environment. Training in recognition of learning styles and supporting learning types are not very useful to a trainee demonstrator; who might benefit more from a recap of basic lab skills, and practice marking followed by discussion of results. Rewarding good demonstrators and ensuring poor demonstrators are not forced to demonstrate again would be of benefit to the system.

Feedback on lab reports from the first year, for the duration of the degree is a primary learning opportunity as this is personalised feedback on work which will represent what they do throughout a chemistry career. On this basis, the formalisation of lab feedback is essential, and as such the training of demonstrators should be to the level of any other teaching assistant or marker in the department. If a consistent format for lab reports cannot be determined by academic consensus then it is essential that the experiments in the carousel system each have a required format for write-up. Penalising students for formatting write-ups in a way they have been instructed to by other academics is self-defeating.

A chance to talk one-on-one with academics, even for a very short time, about submitted essay-style work (or first drafts of submitted work in later years) in the way that postgraduate students have, would allow greater opportunity for real formative feedback, and hence improvement. This is, however, acknowledged to be very time consuming.

The advertisement and support system in place for industrial placements and international exchanges requires improvement, especially in the area of communication. Advertisement of these opportunities should be repeated more frequently and earlier to ensure that students are well prepared for such opportunities. Communication must be clear such that students are aware

what is expected of them, and who they can contact, should they need support whether during the project or in the write-up stage. The weighting of the final report has been lifted slightly, but still accounts for a substantial amount of the year.

Methods For Research in Teaching

Enquiry Based Learning

- A complex topic is introduced, with sufficient opportunity for more open-ended responses.
- Students identify what prior knowledge they have, and what they need to gain.
- Students actively explore the topic in groups, with small group meetings to discuss the topic, helping them stay on topic, and allowing them to identify areas where they require assistance.
- Students are responsible for the analysis and presentation of their work, evidencing the achievement of the learning goals.

Problem Based Learning

- A problem is presented to the students.
- Students in groups, identify what knowledge they need in order to solve the problem, based on prior knowledge. They identify areas where they need assistance from an academic.
- Students engage in independent study, and seek out assistance from academics.
- They present their solution to the problem.
- The solution is assessed by academics, and feedback on the solution is given to the students so that they can identify areas for improvement for the next problem.

Communication

- Analysis of large databases of material (whether self-produced or literature based).
- Using varied methods to communicate findings.
- Sharing understanding by presenting in undergraduate research conferences.
- Discussion groups after independent learning.

In a focus group setting, with a collection of academics and students, we discussed these methods for integration and some case studies where these methods had been implemented.

In discussion on enquiry based learning one of the issues raised was one of learning in depth rather than learning in breadth. While students who study in this way have seen the subject from different angles and appreciate the complexity of the subject, they probably won't have the time

to cover the material in as much breadth. Additionally, there is a constant issue with group work. While students benefit from team work and interpersonal skills, which aren't always recognised, high achievers do not like working in groups due to the assessment process.

While enquiry based learning could be used as a structure to help students who have independently set up small study groups guide their learning, it is difficult to ensure in compulsory groups that all students put in enough effort.

Lectures with prerequisite reading allow the student to independently form some context to the subject before the lecture series starts. Even if this reading has not been entirely understood, the lectures then give grounding to that reading and allow the students to consolidate their learning.

With problem based learning, the students are leading towards an answer that can be marked right or wrong, and so the learning is guided towards a target. Questions posed throughout a lecture series can bring focus on the subject, make lectures more interactive, and encourage students to be aware of their learning. This integration of problem based learning into didactic teaching was raised by the students as more enjoyable.

Students suggested that problem based learning should be introduced earlier in the curriculum to allow the development of the necessary skills to work out how to approach questions you don't immediately know the answer to. This builds confidence through repetition and a slow increase in difficulty. The use of tutorials to pose difficult questions which cannot be immediately answered gives the most realistic indicator of knowledge and ability, because it is difficult to approach those situations without prior independent reading and learning.

Motivated students would work well in either of these methods, but we have to be aware of those students who need more support or encouragement, and the possible detriment to other students caused by those who are lazier.

A way to motivate students towards these techniques is to make it clear to them what employability aspects there are to these methods. While assessment is a worry to some students, employers are looking for those students with

"I've come to do chemistry because I want to be able to solve problems with a really huge chemistry skill set and be able to go and do things with that, useful things. The degree should be there to start training you in using your knowledge."

team work and problem solving skills.

Sample lecture marks, as discussed elsewhere,[12, 14, 24] are often very similar to traditional didactic teaching methods, but what needs to be explored is whether this learning leads to more motivated or engaged students with a more grounded knowledge that they will retain for longer than just until the exam and be able to apply to a range of situations.

Research Integrated with Teaching

The first case study students were introduced to is taken from the Chemistry Department of the Utrecht University, The Netherlands. The Department involves students in experimental methods from day one, and their students are working within a research group by the end of the first year. The links are maintained between students, lecturers and researchers throughout the three years of the BSc. This encourages engagement with research throughout the degree.[12]

The focus group suggested that this would be a beneficial concept if delivered in addition to the current lab program, but could not replace our method for building skills from the first year up into more research based methods in the later years.

Additionally it was pointed out that involving students in research groups from an earlier year might lead to limitations in the depth of experience, or constrain students to one area of research. There is also a debate as to the level of involvement in some research groups - especially those physical or computational research groups whose material is less accessible in earlier years.

The University of St. Andrews in Scotland have a core module in their penultimate year where students are assigned into groups and given a single topic for investigation. This includes literature research, experimental planning and work, analysis of results and presentation.[26]

This was generally agreed by the focus group to be an extension on our third year project. The one thing that was raised as an issue was again the group work issues. In the lab students were uncertain when working together and

"While everyone seems to agree that they're quite happy to work in a group, they might not be particularly happy about being assessed."

referencing each others' lab outputs - it has come to feel like cheating to those students used to working independently. Additionally this is a bigger outlay in terms of postgraduate time, when they are already giving up time to the MChem student in their research group.

Communication Skills

In early presentation practices there is very little discourse. Often the other students are too busy focusing on their own presentations to learn from other students' and the questions asked are very leading and the person asking the question already knows the answer.

Students suggested that the MChem oral exam is a good example of scientific discourse in their undergraduate, as students expect a discussion, with two-way open ended questions. They do not get a chance to practice this kind of synoptic exam at any other point in their degree. However, when asked if they would be interested in practicing by asking questions of PhD students on their postgraduate research, students voiced that they wouldn't want to do that with PhD student because they "know so much more than you". It is interesting that while students are expecting a two-way conversation, they want to be able to ask questions that they already know the answer to, rather than to learn the answer by asking a question.

They would be more interested in a situation where a first year reads a research paper and has an opportunity to discuss the paper with a second year student, which is an opportunity for the older student to pass on methods for gathering knowledge, encourages social discussion of a paper and develops interpersonal skills. The skill of being able to teach material is a key skill which isn't directly developed throughout the undergraduate.

University College London History of Science undergraduates are involved in a communication project that involves taking on a body of research from the previous year group and developing it, with the aim of leading to publishable material.[27] This is how research works within academic groups, where material is passed through generations of PhDs or post docs to develop the academics' broader hypotheses.

The focus group raised that the first year of the project would find this most difficult and would require most guidance, as the body of work does not already exist. There is a possibility that the

students would lack any original ideas or get sidetracked or head in a not very beneficial direction, and so they would need a lot of support.

It was suggested that there could be a way of integrating this idea into the undergraduate labs, where students are given the opportunity to develop the undergraduate scripts and encourage progression at that level. Currently inheritance of this type is limited by a lack of communication between academic years and demonstrators year on year.

In the University of Queensland, Australia, there is a communication project wherein academics or industrial chemists deliver audio interviews on their cutting-edge research, and the students write a short assignment on that interview. There is then an undergraduate conference and further key skills assessments with audio-file feedback provided by PhD students.[28]

The focus group considered that this was overall too complicated, and while it would familiarise students with the respective key skills it would become a hoop-jumping exercise that the students would not appreciate. The supervision by PhD students may be considered to be lowering teaching quality, but also puts considerable strain on the PhD students.

The focus group did appreciate the opportunity to be critical of a peers work and defend their own work, and also the concept of audio-file feedback. The audio-feedback seemed a lot more immediate and personal than written feedback, and also would presumably be formalised which is something lacking in current lab feedback methods.

University of Warwick

Finally, the focus group was introduced to the changes instated in the University of Warwick first and second year chemistry labs, wherein questions at the end of lab reports were exchanged for pre-lab questions to encourage students to think about their experimental process before they started in the lab.[29] This change was used as part of a case study in the HEA book: Developing Undergraduate Research and Inquiry,[12] and shows that the Department of Chemistry is working towards, and is being recognised for working towards, an undergraduate course that supports the student in learning material outside of lectures and preparing for a future in research.

One of the issues highlighted by the students in that system, and in the carousel system was that the pre-lab questions are often designed to get students to explore the surrounding knowledge, rather than helping students understand the aim of the experiment and the method used to carry that experiment out. The prelab should give the student enough knowledge to understand what they are doing in the lab, to fix any problems that occur or find ways around mistakes which are made. The post-lab questions should cover understanding what their results mean, as results are rarely analysed whilst in the lab. While the practical and understanding its context do complement each other, the lab requires more practical understanding of what is going on in the reaction vessel, rather than a detailed contextualisation.

There was a suggestion in one focus group of a lab, perhaps later in the second year, where the script was designed not to work, and the pre-lab carried out by the student would be to determine why the experiment wouldn't work and attempt to create an experiment which would work successfully.

Highlighted as a real positive of current lab methods is that repetition and practice in earlier years leads to recognition of a process and allows the student to be comfortable and confident with practical aspects of chemistry.

Failure in the first year, where the outcome of a reaction is known and the process is well defined, comes from mistakes which are made. In the third year there is a transition into more research-based experiments where students acknowledge that not getting a result or getting a poor or unexpected result can also be due to the reaction not proceeding as predicted. This is the basis of research chemistry.

> "I knew quite well how to put a reaction together and what sort of reactions I was aiming for when I went on my placement. [...] For the first few weeks I needed some pointers, but after that I was able to go away on my own. I couldn't have done that without my first two years here."

Conclusions

The hypotheses under test were as follows:

- The Chemistry Department advertises its course based on its research status and it is this status that brings prospective students in to the department.
- Undergraduate students do not feel involved with the department's research culture until their MChem fourth year (where relevant).
- Undergraduate students do not engage well with lectures delivered in a traditional manner.
- Lecture material delivered in a self-guided or problem and enquiry based manner would engage students more successfully.
- Interest in current research is such that engagement with research would increase motivation and engagement with the core topic.
- The Department offers and supports involvement in industrial, global and research opportunities, but these are not extensively taken up by the students.

From study of the materials delivered by the department to prospective students and the web-based materials that students come across in the process for applications to universities the Chemistry Department does advertise its course based on its research status before teaching and facilities are mentioned. Students suggested that the department being a centre of research excellence was as much of a draw as the advertised teaching quality and job prospects for graduates. The primary reason for the choice of university was due to the league tables and university prestige, and most if not all of these tables feature a proportion of the score which is determined due to the research status of the university, especially in the construction of the world-wide league tables.

The majority of students in the first three years do not feel involved with the research culture of the university, and even a proportion of the fourth year still feel uninvolved or segregated from the postgraduate population. There are few existing opportunities for students to discuss – informally – research with academics and postgraduates. It has been highlighted by academics, the difficulties involved in contextualizing the first two years of the course in terms of modern, cutting edge research as the information being taught is essential, core knowledge – required from progression – but which was discovered many, many years ago. Even so, journal references are included by many academics. Potentially the biggest problem may be that the attitude to learning – for many students – is ‘what do I need to know for the exam?’ It may be the case that

they are not interested in being a part of the research culture – unless it can be shown to improve their prospects or be worthwhile in some way.

Through examination of questionnaire responses it seems that many students feel they learn most effectively in a tutorial environment and interestingly this is where they also learn more about the research culture of the department. The problems highlighted with students with the course were not in the skills and content being taught, but more in the quality of teaching they receive and the attention and support they have from academic staff. Academics expect a minimum of interest from the students, however they do feel the impetus on the lecturer to make lectures interesting. As a lecturer they feel they are 'performing' and trying to produce interest and relate their material with the real world.

Academics expect students to be involved in self-guided learning throughout their degree, but this is not always made clear to the students. This communication break-down needs to be resolved in a manner that doesn't allow the students to claim they 'haven't been told' about academic expectations. In the third year, when students are starting to take ownership of their own learning and lab experiences students are more enthusiastic about the work and are more engaged. Feedback from students is often extremely positive.

Students involved with URSS projects, industrial placements and exchanges abroad return highly motivated towards their own learning, appreciating their own educational background and with a clear path forwards in mind, often into their own research careers or into industry. This motivation is hard to reproduce in any other situation, and so it currently falls to the MChem and limited other experiences in earlier years to recreate this environment in those students who have not attended one of these earlier research opportunities. If there is a method of bringing those experiences into the mainstream degree, that could be equally beneficial to those students.

The department is very well respected for its students in industrial placement and international exchange situations. This has led to a reticence in overt advertising for these opportunities in order to maintain the quality of the students who are motivated to seek out them. However, this is leading to a decrease in the uptake of these opportunities. The advertisement and support system in place for industrial placements and international exchanges requires improvement, especially in the area of communication. Advertisement of these opportunities should be

repeated more frequently and earlier to ensure that students are well prepared for such opportunities. Communication must be clear such that students are aware what is expected of them, and who they can contact, should they need support whether during the project or in the write-up stage. The weighting of the final report has been lifted slightly, but still accounts for a substantial amount of the year. Communication between relevant academics, administrators and the final location is often poor, leading to students feeling abandoned. It has been emphasised that support by the host company or university is often exceptional. Final preparations often seem to fall during exam times. It is possible that students are not aware of how self-driven this process needs to be, and an introduction to this concept early in the first year followed by frequent reminders of the requirements may solve some of these problems.

Overall there is a major opportunity now to increase the integration of research culture and undergraduates, and therefore improve the motivation of the students towards the degree. Whilst it has been identified that making student's carry out compulsory undergraduate research is counter-productive to creating strong research graduates – whom must be ready to seek out these opportunities themselves – there is a group of undergraduates that would benefit from greater awareness of the opportunities available to them. This would be ideally directed by personal tutors, who will be able to give students direct advice or direction of where to get more information on getting involved in these many extra-curricular opportunities. Another option is to further increase student awareness of the role of the careers service. Informing students of the importance of getting involved and doing extra-curricular research is an important step into creating a more integrated student research culture and ethos, which currently seems to be confined to a handful of students in each year.

Resources

Audio files and transcripts from academic interviews will be made available on the project website, along with original questionnaires, questionnaire responses (with all identifying information removed) and other resources and materials. Go.warwick.ac.uk/aligningchemistrycurriculum

Websites and reference materials for background into the broad and contentious area of the nexus of research and teaching are available on the project bookmarks page: www.delicious.com/aligningchemistrycurriculum

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