A. Engaging students in research and inquiry at the beginning of their academic studies

1.1 Improving interactions between first-year science students and researchers through an informal networking program at The University of Queensland, Australia

The Undergraduate Science Students Experience in Research (USSER) Network is an extracurricular program welcoming first year undergraduate science students to the research culture of The University of Queensland (UQ) from their first semester. The primary aims are to increase the frequency and quality of interactions between undergraduate science students and UQ researchers, to help students understand what a career in research entails, and the specific research being conducted by scientists at UQ. Of the three components to the USSER Network (lunches, tours and placements), the main component is the “Meet the Researcher” lunches, during which researchers meet with groups of undergraduate students over informal lunches each semester. These lunches take a round robin ‘speed dating’ format, where 3-5 students and a researcher have a 10-15 minute conversations about research and career paths. Once time is up, the researcher moves to the next table to meet with a second, and finally, a third group of students. At the end of these three rounds, each researcher provides a short biography for the entire group, and students are able to mingle with the researchers they have common interests with for the remainder of the lunch. The design has been shown to foster conversations amongst small groups, and thus provide numerous, personalised interactions between the researchers and over 100 new science students at each event. In addition, students are invited to undertake guided tours of research facilities on the campus, and are supported in gaining work experience with research groups through a placement program.

Sources: Farrand and Myatt (2009); www.science.uq.edu.au/ussr

1.2 1,500 biology students are involved in research at University of Sydney, Australia

First year Biology students at the University of Sydney contribute to the understanding of the prevalence of asthma in Sydney. Each student learns to pour an agar plate which they take home and expose in their back yard over a 10 minute period, to collect a sample of airborne fungal spores in the atmosphere. There are 1000 students in the class and they live all over the Sydney metropolitan area. Once the fungi collected have grown into colonies, students learn to use a key to identify the fungi, and the class results are converted into maps showing the distribution of the different species. This generates new knowledge, which they discuss online with an international expert, and which is fed into research programs on allergens. The students involved reported a better awareness of research, and their involvement in it, than students involved in a practical course which had a traditional textbook demonstration.
practical exercise. Dr Charlotte Taylor describes a thousand students as an 'ideal' size of research team for carrying out research of this nature.

Sources: Taylor and Green (2007); [http://www.mq.edu.au/ltc/altc/ug_research/research_curriculum.htm](http://www.mq.edu.au/ltc/altc/ug_research/research_curriculum.htm)

### 1.3 Introducing students to academic staff research: Department of Geography, University College London (UCL)

All year one students in Geography at UCL do an assignment in term one, in which students interview a member of academic staff about their research.

- Each first year tutorial group is allocated a member of academic staff who is not their tutor.
- Tutorial groups are given three representative pieces of writing by the member of staff along with a copy of their CV, and a date is arranged for the interview.
- Before the interview, students read these materials and develop an interview schedule.
- On the basis of their reading and the interview, each student individually writes a 1,500 word report on: a) the objectives of the interviewee's research; b) how that research relates to their earlier studies; and c) how the interviewee's research relates to his or her teaching, other interests and geography as a whole.

A variant on this entitled ‘Meet your Lecturer’ has been integrated into first year tutorials by other departments at UCL. For example, in Structural and Molecular Biology department students are given a tour of a research laboratory; in linguistics groups of first year students ‘meet a researcher’ in their first week; in another department the output of the meeting is that students make a short video about the Professor’s research.

Source: Dwyer (2001); [https://www.ucl.ac.uk/teaching-learning/case-studies-news/connected-curriculum/meet-lecturer-personal-tutoring-difference](https://www.ucl.ac.uk/teaching-learning/case-studies-news/connected-curriculum/meet-lecturer-personal-tutoring-difference); [https://www.ucl.ac.uk/teaching-learning/case-studies-news/research-basedlearning/meet-researcher-linguistics](https://www.ucl.ac.uk/teaching-learning/case-studies-news/research-basedlearning/meet-researcher-linguistics)

### 1.4 Design-centred inquiry-based learning opportunities for year 1 students embedded within the Integrated Engineering Programme (IEP) at University College London (UCL), UK

From the autumn of 2014, all first year engineering and computer science students enrolled at UCL undertake independent research to inform, guide and inspire their project design brief, ideas and solutions during the first of two 5-week interdisciplinary ‘Challenges’. A principal objective of the IEP is to have students graduate from UCL Engineering skilled with the ability to take on a problem, navigate their way through a process of design, employ ‘engineering thinking’, and generate solutions that are efficacious for all stakeholders involved. The creative, yet iterative, process of design requires continuous questioning, investigation and resilience on the part of the student design teams. As the themes for the ill-defined problems of the two Challenges are steeped in such global challenges as sustainability and health, cultural and community, partners, as well as technical experts, were introduced as part of the teaching team or as external advisors to enrich the student experience. Such collaborations from across the university, within the UK and around the world open up exciting opportunities to embed authentic and enquiry-based learning into the design-centred curriculum of the IEP year 1 Challenges module. When asked to reflect on their team’s experience of using the design process to solve a problem, one student wrote:

“Our initial step was to research into what the actual problem was. We investigated and researched further into the problem to find out about all aspects of the energy problem. We looked at all aspects of the problem, not just the technical bits, and then started to think about some good and viable solutions for the problem. The research helped us come up with ideas. The research was tough though, sometimes I had no idea what I was reading or what I asking the external advisors, but we had many study sessions together as a team and meetings to brainstorm ideas and then we started coming up with some real diverse solutions.”

Source: Correspondence with Emanuela Tilley (e.tilley@ucl.ac.uk); [http://www.engineering.ucl.ac.uk/undergraduate-study/iep/](http://www.engineering.ucl.ac.uk/undergraduate-study/iep/)
1.5 First year students pose questions through observation in biology at ANU, Canberra, Australia

In groups of 12–20 students, students conduct this exercise while walking through the nearby Australian National Botanic Gardens with a demonstrator (TA) as part of the 350 student introductory class on Evolution, Ecology and Genetics. The exercise takes 2 to 3 hours, plus some time to write up afterwards. It gives first year students the liberty to start thinking like scientists, to stimulate their curiosity and to get them talking to their peers. Students are taken for a short walk through the gardens and encouraged to observe their surroundings. They then are sent off ‘solo’ for ~30 minutes to write down 10 questions (e.g. Why do eucalyptus leaves dangle?). Each student then reads one or more of their questions to the group and together the students and tutor restate the question as a hypothesis (e.g. eucalypt trees in arid environments have leaves that dangle at steeper angles than those in wet environments) and design an experiment to test that hypothesis. The exercise builds confidence and comfort with the experimental process, demonstrates what makes a ‘good hypothesis’, and begins to get students thinking about elements of experimental design.

Further information: Adrienne Nicotra (adrienne.nicotra@anu.edu.au); http://biology.anu.edu.au/adrienne_nicotra/

1.6 Changing how first year students view experimental physics as a learning experience: The ‘Secret Objective’ at University College London, UK

One of the problems that 1st Year, undergraduate experimental physics courses have is the way that students approach the discipline. Often their previous experiences have been limited to directed demonstrations rather than experimentation. It is not unusual for students to view physics experiments to be a recipe that they follow to get a ‘correct’ answer. Indeed, some students have said that, in the past, they were quite happy to make up results so that they matched their expectations regarding the successful experimental outcome. This is not what we want physicists to do.

Consequently, a new teaching concept was introduced at University College London’s 1st Year practical physics courses: The ‘Secret Objective’. Students are encouraged to believe that not all of the scripted experiments were as straightforward as they seem. Doubt is placed in the minds of the students about the validity of their preconceptions regarding the outcomes of experiments. They are told that some experiments have been modified so that they will not behave as expected. This can range from the theory in the script not being sufficient to explain the data, to anomalies in the experimental system that cause interesting problems. Indeed, some experiments can have multiple Secret Objectives. Therefore, the students are trained to look for anomalies in the practicals that might have been placed there by the experiment creator. Breakout sessions are used to discuss what they think the ‘Secret Objective’ was so that a discussion can take place regarding how career physicists approach experimental challenges and unexpected findings.

Consequently, they actually analyse their experiments rather than purely copying values in their laboratory notebooks without any critical thought. They actively observe in a way that is quite new to them. Indeed, they often find Secret Objectives that are not placed there by the experiment creator but are there as a result of the real physics. That is what we need them to do and ‘Secret Objectives’ are a means to do this. It is habit forming.

Further information: Paul Bartlett (paul.bartlett@ucl.ac.uk)

1.7 All first-year biologists have research experiences at Cornell University, US

The ‘Explorations Program’, which has been running since 1991, introduces Biology first-year undergraduates to research by Cornell faculty in the context of a course of 700 to 900 students. Large-scale funding has created 100 to 120 ‘experiences’, each of approximately three to four hours, for groups of six to eight students. Most are designed to introduce students to the kinds of research problems on which the faculty member works. Programmes take place both in research labs on campus and at field sites near campus. The programme is structured so that each student is required to participate in one ‘Exploration’ per semester. For example, recent explorations have varied from ‘how do you tell if animals have color vision?’ to ‘why do sperm whales swim in circles?’
1.8 Scientific Communications 101: A student organised science conference at Curtin University, Australia

Students in an introductory year one course with a linked focus on physics and science communication were required to plan and present a one-day Physics conference. The context was an institutional requirement that employment focused communication skills be integrated into disciplinary programmes. The idea of a student-organised science conference, publication of the proceedings, and the reasons for the approach were explained to students in the first Physics class. For the following week, students were asked to decide on a Physics topic they were interested in presenting at the conference, the overall theme for the conference, and how all the students would contribute to the organisation of the conference and the publication. Later in the term the conference took place over a day and staff and students from the department and local high school students and their teachers attended. In the years that the course ran it succeeded in helping students develop more effective communication skills linked to their discipline, introduced them to research debates and helped them begin to think and communicate like physicists.

Source: Zadnick and Radloff (1995)

1.9 Terrascope: First year geoscience and engineering students investigate a complex problem at Massachusetts Institute of Technology (MIT), US

Terrascope is a cross departmental optional programme for year one students. Each year addresses a different theme, for example, tackling global climate change by removing carbon from the atmosphere. The pedagogy is ‘problem based learning’ with a minimum of structure, but with a range of support from faculty, librarians, upper-level students and alumni mentors.

In semester one, students form themselves into groups of 5-10 and develop their understanding of possible solutions to the chosen issue. Each team has to “produce a comprehensive web site that outlines the problem and how they propose to solve it” (Bowring et al., 2014). In the second semester the main offering is a class where students are presented with a range of research questions relating to that year’s theme and investigate these in teams. Each team has to produce a booth filled with resources which demonstrate their research topic. These are then presented at a public ‘Bazaar of Ideas’, where members of the public and faculty question the students. The other semester two option ‘Terrascope Radio’ focuses on public dissemination of student work on the theme. Each group produce a programme which is broadcast on MIT radio. Terrascope students can also choose to join an annual spring field course, often in an international venue, on that year’s theme.

Entry to the programme is effectively by student choice and each year some 100 students enrol but “it is not uncommon to lose a third by the end of the third week. Students who continue become deeply engaged in the class” and produce high level work (Bowring et al., 2014).


1.10 First year design through problem-based learning in Mechanical Engineering at University of Strathclyde, UK

Students are aware that they will undertake a ‘Mechanical Dissection’ of a car before enrolling at university: the exercise is highlighted in the degree prospectus and open days. At the beginning of the first year, the structure of this class is explained to the students so that they know when in the year they will be working on the car dissection. It is also emphasised that the tasks they must undertake are related to the development of research skills for later in their Course. Each student group spends a couple of hours selecting a part of the car (for example the front or rear suspension, or a part of the braking system) and removing that part. The following day each group meets with two lecturers to discuss the physical principles behind the component’s function, and to select a couple of parts for further examination. These parts are examined under the microscope to ascertain the materials and processes involved in
their manufacture. The students then have (in the style of Problem-Based Learning) to research the functions, physics, manufacture and design of the components, and to produce a poster explaining these. They present their draft poster to two members of staff, who discuss the content with them and inform the students of any further work necessary to bring the poster to an acceptable standard. The students then have to produce a brief PowerPoint presentation covering the same material as the poster for a conference plenary session at which two students, chosen at random, from each group describe their component to the rest of the cohort. After their presentation, each group has to field a couple of questions from one of the other groups of students. In preparing the poster and presentation students will need to explain topics not covered elsewhere in their first year course. The overall aim in developing this class was to show the students how the rather theoretical academic work they cover in their lectures is relevant to the practical challenges of engineering. The tasks associated with producing the poster and presentation also build skills in team work, research skills and communication and encourages independent learning. The students said this exercise ‘is probably the only thing that everyone spends the whole first year waiting for’, it ‘expands on so many skills’, and that it ‘allows you to see how an engineer would think’.

Source: Land (2013)

1.11 Inquiry-based learning in large first year biology class at University of Guelph, Canada

In 2010 a new first year biology course (BIOL 1070 Discovering Biodiversity) was designed for 1800 students in which in-class interactions with the instructors function to guide students through the analysis of case studies in active research. This pedagogy fits the University of Guelph’s strategic plan which emphasizes learning as a challenge of discovery, rather than a problem of storage. The course’s major theme is the causes and consequences of biological diversity, which provides the conceptual framework in which skills development takes place. The objective is to excite students about biological inquiry and major issues in biodiversity science with the use of controversies in biology, case studies, guest researcher presentations, small group tutorials, and hands-on inquiry in lab and field research projects. Students in sections of 600 are engaged in:

- Two 50 minute in class interactions per week
- One 50 minute seminar per week (~30 students + Teaching Assistant)
- Regular online workshops and activities that coordinate concept and skill development.

The in-class interactions focus on inquiry cases that explore both skills and major concepts. The first case study, “Invasion! Mussels of the Great Lakes Regions” is based on a serious and current concern about loss of biodiversity in mussel species in the Great Lakes and watersheds. The second inquiry case, “Forest Biodiversity” is based on controversial issues surrounding species diversity in forests and conservation biology. The third inquiry case “An Arctic Ecosystem 8ºC Warmer” concerns climate change and the impact on arctic organisms. In class interactions involve active learning approaches (e.g. small and large group discussions, use of electronic clickers) and mini-lectures. Information is fed to students on-line on as needed basis, which is like an on-going narrative of a real life project. In the lectures the students are engaged because they want to know the next part of the story and how to deal with the current problem, research challenge or question. Seminars emphasize skills development (especially modes of scientific inquiry) and small group interactions. Students meet weekly with a graduate student Teaching Assistant and the same group of ~30 students.

Sources: Correspondence with Steven Newmaster; http://www.uoguelph.ca/ib/pdfs/W12/W12_BIOL1070.pdf

B. Final year and capstone projects

2.1 Giving students first-hand experience of research-based consultancy in environmental management at University of Queensland, Australia

Team-based problem-based learning in used in the final year capstone course for the Environmental Management, Rural Management Environmental Tourism and Tropical Forestry degrees at the University of Queensland’s Faculty of Natural Resources, Agriculture and Veterinary Science to give students experience of research-based consultancy. It is
a year-long course, team taught by an interdisciplinary staff (in recent years, a social scientist and an ecologist for the internal students, a multi-skilled environmental manager taking the external students). The staff solicit suitable ‘problems’ and clients among their contacts, for instance from government agencies, non-governmental organisations, or land care groups, or the private sector. The staff may help the client mould the topic to achieve appropriate degrees of difficulty, and equity in workload and difficulty across the student groups. The students work like consultants to their client, coping if the client changes the brief during the year (as many do a couple of times). They work in groups of about six students. The clients come to campus at least three times, for an initial briefing to their students, and presentations at the ends of first and second semester. They liaise with the students all year, usually off campus at their offices, and by phone and email. The staff give a flexible program of lectures in first semester, to prepare the students with skills they need towards each forthcoming step of their tasks, and in group processes. At the end of the year their report is 'published' (printed and bound) for the clients. Peer and self-assessment are used to distribute group marks among the contributors.

*Source:* Correspondence with Helen Ross, 2006

### 2.2 Giving students alternative assessment options for undertaking a product design project at Nottingham Trent University, UK

The course offers several possible routes. Assessment is based on a learning contract negotiated and agreed between the tutors and student. This contract stipulates the content of work, enabling students to complete one of the following options:

1. a 10,000-word dissertation and students produce a poster that summarises their work;
2. a 5,000-word conference paper with a supporting presentation delivered to peers and tutors;
3. a conceptual project with a 5,000-word critical justification. As well as a written outcome students are required to produce illustrations or simulations.

Prior to students undertaking their chosen assignment, there is a three-week intensive period when students complete a learning contract. The contract identifies what option the student will complete, what they hope to learn and how that learning will be demonstrated. The module involves students using a wide range of primary and secondary research skills.

### 2.3 Alternative Final Year projects in the Biosciences at the University of Leeds, UK

Final year students within the Biomedical Sciences group of programmes (Human Physiology, Medical Sciences, Neuroscience, Pharmacology) have the opportunity to undertake one of the twelve types of research project. Each project is of 8-weeks duration, with students expected to commit 3.5 days per week to their project. Students are provided with a list of projects (with project descriptors) in March of the year preceding their final year and invited to choose, in rank order, 10 projects they would like to be considered for. Projects are then allocated based on student choice and ranking within the year group; with projects starting in the January of their Final Year.

The assessments for all project types are similar. Students are required to write a 25-30 page dissertation and deliver an oral presentation. Students undertaking critical review projects also have to submit a 5-page grant proposal linked to their review. There is also a supervisor allocated “productivity” mark.

**i. Individual laboratory projects**

Students undertake an individual programme of research in the laboratory of their project supervisor, often contributing to ongoing research within that laboratory.

**ii. Group laboratory projects**

Students work collaboratively, in a team of 3-4, to undertake a programme of research, based either in their supervisor’s laboratory or in the teaching laboratories. The format of the project varies between groups; they could all be undertaking similar studies or addressing different elements of a research question (e.g. using different techniques or pharmacological agents). The design of the studies and ongoing development of the project is decided collectively by the group. At the end of the programme of research, all data is shared, but each member of the group writes their dissertation and delivers their oral communication independently.

**iii. Computer simulation projects**
Students investigate the function of biological systems using established computer models (e.g. human cardiac myocytes). Students are trained in the use of these models (e.g. to obtain and plot ionic currents, action potentials, action potential durations etc). They then challenge these models.

iv. **Bioinformatics (plus) projects**

Students undertake data-mining exercises of publically available databases (e.g. to identify candidate gene sequences); the area of interest decided in consultation with their supervisor. The information gained will then be utilised in subsequent laboratory studies undertaken by the student (e.g. transfection of DNA into cells; human physiological studies).

v. **Critical review projects (with linked grant proposal)**

Students undertake a hypothesis driven critical review of the literature in a specific area/topic within the biosciences. They agree a research area/topic with their supervisor, construct a hypothesis and then search, evaluate and critically review the literature in this area to provide key arguments and evidence, both in support of and against their hypothesis. They then write a dissertation and a 5 page, self-contained, fully-costed grant proposal for a 1 year pilot study which, if undertaken, would advance scientific knowledge in one area of the research they reviewed.

vi. **Therapeutic or scientific audits**

Students undertake a meta-analysis of published data e.g. clinical trials, scientific techniques or protocols. For therapeutic audits, they will undertake a meta-analysis of published clinical trials to investigate the effectiveness of different therapies in an area of their choosing (e.g. effectiveness of pharmacotherapies versus lifestyle interventions versus bariatric surgery in the treatment of obesity). Statistical analysis is undertaken using open access software available on the Cochrane Collection website. They then use publicly available databases to expand their study and put the results into a wider context (e.g. post-code lottery prescribing, cost-effectiveness of treatments, prescribing patterns in different countries). Scientific audits are an evaluation of scientific techniques or protocols in a particular field e.g. the impact of husbandry and housing on preclinical research data obtained from laboratory animals.

vii. **Survey projects**

Students undertake a survey of the public’s attitude to a topical biosciences or health-related issue. In consultation with their supervisor, they decide their research question and client population (e.g. Evaluation of Fit-Fans, a lifestyle/health promotion programme for male rugby league supporters, attitudes to the use of legal highs or whether laboratory animals should be used in undergraduate education). They then design a questionnaire, evaluate its effectiveness through focus groups before using it to survey their client population(s) by conducting semi-structured face-to-face interviews. Students are required to compare a minimum of at least two populations or client sub-groups. On completion of the survey, they may put their results into a wider context by undertaking an extended, face-to-face interview with a key stakeholder (e.g. Head of the Primary Care Trust for the above Fit-Fans intervention) or look at environmental or other factors.

viii. **Science and Society projects**

Students create, deliver (up to 13 times) and evaluate an interactive, curriculum enhancing teaching in local primary (students aged 7-11) or secondary (students aged 13-18) schools. Students design a teaching session on their allocated topic. It must be interactive (i.e. not a didactic lecture) and curriculum enhancing (i.e. be part of the national curriculum), but something the teachers themselves can’t deliver (e.g. though lack of equipment, recent advances in science etc). The session must be modifiable for different year groups or session lengths. It must also incorporate a means of evaluating student knowledge acquisition, and feedback from both students and staff.

ix. **Science communication and Public engagement projects**

Students create, disseminate and evaluate resources to engage different with complex science e.g. infographic’s or animations to inform on the science behind a commercial company’s products or patient information leaflets to promote statin use. In consultation with their supervisor, they decide the target audience, ascertain the provider’s (company, GP etc) public engagement needs or objectives, identify the most appropriate means or resource to communicate this information, create this resource and engage their target population with it, evaluating its effectiveness.
x. **Educational development projects**
   Students create and evaluate learning resources for use in undergraduate teaching. Working either individually or in small teams, students develop learning resources or new teaching methods (e.g. social media) to support ongoing teaching. The resources developed address needs identified by their supervisor (e.g. challenging topics). Students decide the most appropriate format (e.g. online data analysis tutorial, multimedia presentations, wiki). The resources are then implemented into the curriculum and the students evaluate their suitability and effectiveness using surveys, focus groups and interviews.

xi. **Digital resources projects**
   This is an extension/ modification of educational development projects. Students will create an interactive digital learning resource for use in undergraduate teaching using the open source, e-learning software Xerte. The topic of the resource and the interactive content (e.g. videos, web-links, quizzes etc.) to be decided in consultation with their supervisor. Given the time constraints of the project, it is unlikely that students will be able to implement the resource they have created into the curriculum and therefore evaluation of its quality and effectiveness will be provided by focus groups.

xii. **Commercial projects**
   Students will write a technical, market research or business report for an identified business client (e.g. market research on their/their competitor’s products; evaluation of the impact of new legislation).

All of the above project formats can either be individual or team-based projects. The latter have grown in popularity (e.g. 60-70% of the lab projects are now group based and most ask for the non-traditional ones, to be run as a group). Data is collected by the group and students sort out an equitable allocation of work themselves. However, assessment, both the written dissertation and the oral presentation, is individual.

**Further information:** [http://curriculum.leeds.ac.uk/rbl/final-year-project](http://curriculum.leeds.ac.uk/rbl/final-year-project) or email d.i.lewis@leeds.ac.uk

2.4 Chemistry ‘Concentrated Study’ Project at the University of St Andrews, Scotland
   This is a core course done by all 3rd year chemistry students (within a 4 year BSc/Syear MChem framework); current enrolment is 48. It is taught in the last four weeks of the Spring semester. Students have no other class and are able to spend their full time on this module. Students are divided into (mixed ability) groups of five - six each assigned to an academic supervisor who assigns a topic for investigation. This requires some literature research, experimental planning, experimental work, analysis of results and their presentation. The projects assigned vary but generally fall somewhat short of original research while maintaining substantial scope for student input to the direction of the work and how to best achieve the goal set. The module has run for the last five years and typically yields grades rather similar to conventional laboratory classes at this level. A consistent observation however is that this really brings out the best in some otherwise weaker students who seem to be inspired by the idea of contributing to the team effort in a way that is not achieved in a more conventional class. It provides a sound preparation for those students who go on to take an honours project.

2.5 Preparing and Defending a Consultancy Report in Environmental Geology at Kingston University, UK
   Each student in a final year module is given an environmental geophysics problem and is asked to role play being a consultant recruited to address this problem for a client, either a local authority or a private land owner. They are required to design a solution, interpret field data and present their findings in a technical report and verbal format. Students are required to prepare and deliver a solo presentation to an open public meeting (20 minute session, including 5 minutes for fielding questions) describing their problem outline, methodology, data interpretation and recommendations. The audience includes Councillors (soon up for re-election) and members of the lay public (staff members and other students) who have a vested interest in the environmental issues. A disruptive group of 'eco-warriors' (usually noisy postgraduate students) also make an appearance! During their presentations, students must show appropriate local and environmental considerations and effective handling of heckling from concerned local residents and the 'eco-warrior' group.
2.6 GEOVerse: A national journal for undergraduate research in Geography at Oxford Brookes and three other universities, UK

GEOVerse is a national undergraduate research journal for Geography which has been piloted in four institutions. The geography departments in Oxford Brookes University (the lead institution) Queen Mary, University of London, the University of Gloucestershire, and University of Reading comprise the editorial board of the journal. GEOVerse publishes student-led original research based on theoretically considered and empirically-based investigations undertaken at undergraduate level. The aim is to motivate and reward students for producing innovative and best undergraduate research practice, and then give them support through the review process before disseminating their work through publication. Papers are reviewed by a panel of postgraduate students.

Students at Oxford Brookes undertake a compulsory second year module called Geography in the Field where they go on a field trip and work in groups and collect data. An optional third year honours module was created in which students could write up their research as a paper with supervisory support from a tutor. This resulted in many students becoming authors of research papers but in a supervised manner. This helps fill a gap in the research cycle for undergraduate students because they did not get the same kind of constructive, meaningful and useful feedback that an academic would get from going to conferences, putting papers in, and getting feedback from peer reviewers. In this module students get dialogic feed-forward on their work and they are provided with an opportunity to disseminate their research through organizing a set of undergraduate conferences as well as the opportunity to publish in GEOVerse.

The work has also impacted on the work of colleagues in other institutions and transformed their curricula. Colleagues at the University of Reading have replaced an examination with writing a journal article for GEOVerse. The University of Gloucestershire has developed a collaborative writing assignment in which students write a collaborative journal article. At Queen Mary, University of London they have an expedition to Iceland. Students are given the opportunity to produce a research paper on their return.

2.7 Final year students undertake team research projects on local environmental issues at the University of Gloucestershire, UK

Issues in Environmental Geography ran for about a decade at the University as a final year capstone module; and an earlier version ran at Coventry University for several years. Students worked in groups of 4-6 on local environmental issues. The module was concerned with analysing competing environmental philosophies, applying them to understanding a particular local or regional environmental issue and coming up with policy recommendations. The students developed their own projects, starting with a proposal. They were supported through two key lectures on environmental philosophies, a workshop on effective teamwork and individual group tutorials on their chosen topics. The semester long course was assessed through a group report (60%); oral presentation of project (30%) and an individual learning journal and reflective essay (together counting for 10%). The marks given for the group project were redistributed among group members using peer and self-assessment of the quality and effectiveness of their contributions on a five point scale to five group processes (ideas and suggestions; leadership, group organisation and support, minute taking; data collection/ collation/ analysis; report writing, production and editing; and preparing/ giving verbal presentation). The average mark for the module was consistently c3-5 percentage points higher than for other modules reflecting the benefits of working in teams. The difference in marks was confirmed by the external examiners.

2.8 Collaborative and Student-driven Learning Approaches to Capstone units in ICT at Macquarie University, Australia

The Systems Engineering Project was designed to create alliances between top computing students, academics and industry to the benefit of each party. Student groups are engaged in a variety of research and development projects, including; investigating for themselves how the company works, what the problem really is, what are the range of solutions, how does this technology work and so on, and writing these up. To ensure that each team member gains the most from the experience, the roles within our teams are rotated; significantly everyone must have a turn at being the project leader. Decisions made regarding the various design and management choices must be justified and be
based on the environment they are working within: thereby providing students with greater autonomy and ownership of the project.

2.9 Research into Practice: An Alternative Format for Final year Bioscience Honours Project, University of Plymouth UK

Research into Practice is a new module which includes a research proposal as an assessed element, instead of having the bulk of the marks weighted onto the writing of a project report/dissertation. The new format encourages more external employer engagement, if the student wants to explore this opportunity. This module is beneficial to students wishing to pursue careers such as teaching, and is beneficial to students who want a more directed approach. There is also a traditional format module offered to students. The new format involves a group of students signing up to a single project where the protocol for data collection is largely written by the project advisor. Data collection is then carried out by the group and results are pooled, before being analysed and written up on an individual basis. The new format is similar to an extended laboratory investigation and consequently, the project advisor is largely responsible for the planning and any risk or ethical assessments. Projects that have used this new format to date involve an investigation into the ergogenic effects of caffeine on exercise performance and also the effects of a particular growth medium on the culture of young plants. As students taking projects in the new module format have not designed their own research study, they have to carry out a separate research proposal assessment to meet this learning outcome. They need to identify a research question from a literature review they have carried out and then design an appropriate study around this issue. The proposal allows all the planning and design learning outcomes to be achieved, albeit after students have carried out the data collection and analysis elements. The research proposal is guided by a template and although the student does not have to carry out the proposed study, it does need to be realistic, affordable and capable of being completed by an undergraduate student.

2.10 The Mechanical Engineering Final Year Project at University of Adelaide, Australia

The final year project in the School of Mechanical Engineering aims to provide solutions to engineering problems related to industry or to scientific research, with emphasis on project management and effective communication. It is considered to be an important part of the engineering education process and projects sponsored by local industry are strongly encouraged. Industry sponsored projects enhance student skills through relevant real-world projects in research and development, and profits industry by collaboration in training expertise transfer, innovation, and development. Students work in teams ranging in size from one to a dozen. Although the projects require a minimum of 330 hours of student time, many students spend over 600 hours and some up to 1000. The scope of the projects is often ambitious, such as the design, build and launch of a supersonic combustion RAM jet, or a Formula SAE racing car. Students are encouraged to suggest projects themselves as these often lead to outstanding outcomes. The projects are facilitated by the extensive resources put in place by the School to support the students including the provision of a project budget and access to workshop staff time and manufacturing facilities. Each project has at least one academic supervisor, and in the case of industry sponsored projects, an industry-based supervisor.

2.11 Communicating Maths at the University of Bath, UK

Communicating Maths is an optional module for third and fourth year students in the department of mathematics. The project aims to provide mathematics students, who are traditionally poor communicators, with the opportunity to demonstrate competency with these skills and to evaluate their ability, whilst increasing student interest in teaching careers and provide ambassadors of mathematics and the University of Bath within the wider community. The students involved undertake a wide range of activities designed to enhance and broaden the public understanding of mathematics, with a particular emphasis on working with local schools. All of the students on the course attend training and over the course of one semester undertake four tasks:

1. ‘Bath Taps into Science’, a science fair based in Bath during National Science Week. Undergraduates work in teams of four, running a half day exhibition on a subject of their choice which they have researched.
2. Mathematics master class for school pupils aged around 13 led by the students.
3. The third task is drawn from a number of different options. This can vary from students choosing to deliver a lesson in a local primary or secondary school (working with a local teacher), to working with Maths Inspiration, Dr Maths, or with the Further Maths Network.
4. Research and produce a permanent piece of work on a mathematical topic of their choice. Various mediums have been used including posters, web-sites, a YouTube video, and newspaper articles.

2.12 Bioscience End of Year Project at Durham University, UK

Bioscience students at Durham University have a choice of three different types of final year project

(a) Laboratory-based project
The laboratory-based project provides an opportunity to participate in the research being carried out by staff in the School. Many students are able to work in the research laboratories, alongside postgraduate and postdoctoral researchers, and all students have access to the full array of research facilities in the School. The project currently takes place over 5 weeks of full time research, and students are given a piece of work that can lead to concrete results in this period. Many undergraduate projects have generated data that has subsequently been incorporated into scientific papers, with the student as a named author. The project is assessed through a report, written in the form of a mini-thesis, and a short presentation. This module gives the student a taste of scientific research, and exemplifies the School's commitment to providing research-led education.

(b) Biology Enterprise
Biology Enterprise (BE) is project-orientated module, based on research in a commercial context, with self-selecting groups of 5 or 6 students working together. The learning context for BE follows the real-life scenario of the formation of a biotechnology spin-out company from an academic biosciences research group. Within this context BE aims to introduce students to: key processes of business start-up, specifically in the context of a spin-out of an innovation generated as a result of biological research; key factors and considerations that influence the decision making process of the commercialisation of biotechnological innovation; the necessary skills, knowledge and resources required to take biological innovation from concept through to credible commercial propositions; the purpose of a Business Plan and, using a self-generated idea, how to prepare and present a Plan for a research-led biotechnology spin-out. A core component of BE is an in-depth desk study of a biological topic to collate, review, critically appraise and present the scientific research evidence that underpins the self-generated idea for the biotechnological product or process. The content of this module provides an introduction to key business processes such as ideas generation; market research; protection of intellectual property; raising finance, in addition to developing individuals' team working, project planning, time management and transferrable skills.

(c) Biology into Schools
For students who see their future in science education, or other communication-based activities such as journalism, the Science into Schools module may provide an attractive option. As for the other research project options, it is research-led, but in this case the research takes the form of a systematic inquiry into the teaching and learning process. Students are required to prepare materials for teaching science in secondary schools, and to interact with teachers and pupils. After an initial training period, students spend at least 4h per week for 10 weeks in a local school. They are expected to graduate from classroom observation, to assistance in teaching, to an opportunity to undertake whole class teaching. They will also devise a special Biological Sciences project for the school, which they implement and assess. The module is assessed through a journal of activities, reports, a presentation, and a report by the host teacher. This module is focussed towards developing communication skills, as well as team working and interpersonal skills. This module is only available to a limited number of students, determined by participating schools.

2.13 Bridging the gap between textbooks and scientific research: Cell biology at the University of Utrecht, Netherlands

A third year course for cell biology majors focuses on writing and defending of a research proposal as an open ended authentic assignment; i.e. modelling much of the authentic research experience of cell biologists, but not the actual laboratory research: and includes student teams writing a PhD proposal. It builds on the more textbook-orientated knowledge and limited controlled laboratory experiences in years one and two. The 15 week course, with some 24 students has these components:
- A general research topic is defined by staff, and students read selected research papers with a focus on research methodology and research questions.
Students are divided into four groups of six and out of class formulate a research question and methodologies. They also visit relevant research laboratories, contact experts and discuss their proposals in class with their fellow students and staff.

Student teams present their final proposals to a jury of four staff (two cell biology specialists, one biologist, and one non-biology scientist). The broad composition of the jury requires that the proposal should be clearly formulated for both specialists in the field and for non-specialists.

Students then take an extended senior research thesis (usually in the summer semester and often extending into the summer vacation). Some students will work in the lab of jury members, as they were invited by them to do their research project with them. Six years of course evaluations and also a survey of alumni has shown the initial difficulties students face in moving beyond textbook knowledge; the value of the various components; and the course’s success in helping them to think as scientists and better appreciate how research is conducted.

2.14 Students undertake paid internships as agents of change or educational researchers in biosciences at the University of Leeds, UK

The Faculty of Biological Sciences, University of Leeds has recently begun to run two programmes of non-laboratory based internships for first and second year students. These provide good training for students who opt to take the educational development dissertation option. The first, badged as “Students as agents of change” is where students work in groups to develop a resource to enhance the curriculum; it can be something they have identified themselves as being needed within their programme or a project initiated by a member of staff. The second scheme is where the intern contributes (individually) to an educational research project. Examples of ongoing projects include podcasting of research seminars for student/staff use; improvements to educational environment; collation and evaluation of Open Educational Resources for teachers/students. Start-up funding for these internships was obtained from the University of Leeds Academic Development Fund and the Leeds for Life Foundation. These internships are extremely popular, with 63 applications for 18 internships in September 2011. A second tranche was made available in January 2012. Students undertaking Students as agents of change projects agree the number of hours required to complete their project with their supervisor and are paid in installments when they meet defined objectives/milestones.

Educational research interns are paid, in two installments, for 75 hours work. For both schemes, academic support and advice is provided, as required, throughout the internship, a true collaborative partnership between the intern and supervisor to meet the agreed outcomes. Students are required to blog their initial aspirations, reflect on progress and the skills gained throughout the internship and provide an end of internship case study. The Faculty has incorporated the resources into its teaching and its public engagement activities and has committed to the continued funding of the scheme.

C. Departmental and course team strategies to mainstream undergraduate research and inquiry

3.1 Co-ordinated interventions in Zoology at University of Tasmania, Australia

The department has developed a set of linked strategies/interventions including:

**Year one** (approximately 200 students)
- Workshop on the use of animals in research: students put in the position of researcher, considering experimental design and animal ethics to complete an animal ethics application.
- Throughout the year, students encouraged to interact with a web portal ([www.zoo.utas.edu.au/rir/rir.htm](http://www.zoo.utas.edu.au/rir/rir.htm)) with links to ‘Hot Topics’ in Zoology related to lecture material.

**Year two**
- An assessed task over several weeks, in which real, experimental data is given to the students for guided analysis and preparation as a manuscript for publication.
Year three
- Courses include group research projects, critical reviews of current literature, writing research grant applications, lectures from scientists outside the school and training in scientific communication.
- In the Zoology Research Unit individual students are matched with an academic supervisor to complete a semester-long research project.
- Selected students work with academic staff to prepare a research paper for *Nexus Journal of Undergraduate Science, Engineering and Technology* (www.utas.edu.au/scieng/nexus/).

Years two and three
- All invited to participate in Student Research Volunteers programme (www.zoo.utas.edu.au/volunteers/summvolunteer3.htm). Volunteers are matched with mentors, usually postgraduate or Honours students in the School, for short-term, in-house research placements that may offer either laboratory or field experiences.

Years one, two and three
- ‘Reach into Research’ seminars held several times each semester (www.zoo.utas.edu.au/rir/rir2&3.htm). Speakers from industry, collaborating institutions and School PhD students present their research, and then all non-undergraduate audience members, except the facilitator, leave the room.

Further information: Edwards et al. (2007); http://www.utas.edu.au/zoology/

3.2 Curriculum Designed to Facilitate a Student’s Journey toward Self-Authorship, Samford University, US

The geography department at Samford University recently redesigned their department’s curriculum guided by goals of increasing student engagement with the discipline, improving their practical skills, and enhancing their ability to solve complex problems and engage in critical thinking. Core modules provide basic instruction, but these introductory modules incorporate case studies, problem-solving, and active engagement with the subject matter. Students then proceed through a series of elective courses and finally to a series of courses called “Geography in Practice”. Here students have the option of doing a supervised externship, acting as a teaching assistant for an introductory class, or doing an independent research project.

These experiences provide students with an opportunity to link their prior coursework with practical workforce skills. Finally, all students complete a capstone experience where they may either undertake a client-based project, or may elect to do a traditional research paper. With the client-based projects, students work in teams with an outside client to define a problem, devise a work plan and create some distinct output. As examples, students have produced a series of maps for a local bicycle club, worked with the university’s disability services on an accessibility map of campus, and collaborated with an environmental agency to study sedimentation in a river.

All capstone students are assessed on a range of skills, as well as informational and quantitative literacy. As students progress through the curriculum they are expected to take increased responsibility for their own learning and to develop the intellectual skills necessary to move beyond the campus and into society.

Sources and further information: Moore et al. (2011); http://howard.samford.edu/geography/

3.3 Auditing and developing student research skills at the University of Adelaide, Australia and the University of Reading, UK

Selected departments at the Universities of Adelaide and Reading have systematically audited department-based undergraduate and postgraduate programmes for the extent to which they develop student research ‘skills’. The University of Adelaide has developed both a conceptual framework on student research development and based on this, a diagnostic tool to support interventions to strengthen student research skill development in courses. Thus two consecutive first-year courses in Medical Science have adapted their assessment tasks explicitly and systematically to develop student research skills in accordance with the Research Skill Development (RSD) framework. A broadened application of the framework has been developed, including with laboratory-based and numeracy-rich research, as well as with other disciplines and departments, including Petroleum Engineering, Nursing and English. This has led to the development family of Models of Engaged Learning and Teaching (MELT).
The framework is publicly available for other institutions to adapt. Within departments methods to collect data on undergraduates' research skills teaching and learning can be time-consuming and ineffective. At the University of Reading a related electronic 'research skills audit tool' has been developed for academic staff to map systematically research skills teaching and assessment within their own modules.

Further information: Willison and O'Regan (2006, 2007); Fraser et al. (2007); https://www.adelaide.edu.au/rsd/

3.4 Students across all three years of an Environmental Studies degree course worked together on local sustainability projects at the University of Sunderland, UK

Students on an Environmental Studies degree at the University of Sunderland undertook local sustainability projects, which brought levels 1, 2 and 3 students together in small research groups to work in collaboration with Sunderland City Council's Local Agenda 21 personnel, and other local environment and development agencies.

Further information: Hughes et al. (2001)

3.5 Students run the Journal of Non-Significant Differences at Grand Canyon University, USA

The Journal of Non-Significant Findings is a student-run, peer-reviewed journal designed to provide learners with a comprehensive understanding of the research cycle and the publication process. It started as a university-wide initiative in the doctoral college, but now includes students at all levels (undergraduate, masters, doctoral) in both the process of managing the journal as well as in the paper submissions. In 2013 the journal was re-launched and submissions are open to students from any university or college. Central to the journal is an understanding that research does not have to be significant to provide valuable insight into scholarship. As such, articles are evaluated according to the soundness of the research process and the ability to contextualize the importance of non-significant findings.

Source: Correspondence with Jean Mandernach (jean.mandernach@gcu.edu); http://cirt.gcu.edu/research/nonsignificant

3.6 Tutorials enabling students to connect across year groups in Biomedical Engineering, UCL, UK

Tutorials provide an opportunity for students to reflect on their learning, make holistic connections between modules and see their subject in a broad context. We have restructured the tutorials in our Biomedical Engineering programme so that each tutorial group includes students from all years of the programme. The main reason for this change was to encourage students to connect between year groups so that newer students can learn from more experienced near peers and so that students reaching the end of their programme can recognise how much they have learned and matured.

This approach gives practical help to newer students by involving established students in tackling the problems they face, allowing them to form their own support groups organically without the commitment required by a formal mentoring programme. Pedagogically, we aim to use tutorials to emphasise continuity throughout the degree, enabling students to form connections between their learning year-by-year, and to see how their understanding and expertise develops through the programme.

An initial feedback questionnaire suggested that students in the later years of their degree felt that they would gain less from this scheme than new students. We have tackled this concern by scheduling tutorials to ensure that each session contains material relevant to all students and by retaining year-group tutorials in cases where there is material that is only relevant to one year group. An additional benefit is that the tutor’s role increasingly becomes one of facilitating problem solving between students. This means that the tutor needs less programme-specific knowledge, allowing a broader range of staff to get involved in tutoring. We are reviewing the new tutorial system by monitoring students’ feedback with questionnaires, which we will use to refine our approach as the programme develops.

Source: Fung (2017, 130-131) Vignette submitted by Adam Gibson, Professor of Medical Physics, UCL.
Table 1: The Connected Curriculum in 20 Questions: Key questions for departments and programme teams

**Core principle: Students learn through research and enquiry**

1. Are students encountering specific questions addressed by researchers and learning to articulate their own research questions, at every level of study?
2. Can we adjust our teaching methods, student assessments and other aspects of departmental practice to prioritise engaging all students actively in research and critical enquiry?

**Dimension 1: Students connect with researchers and with the institution’s research**

3. Do students have regular opportunities to learn about the institution’s research and other current research relevant to their studies?
4. Are students meeting with researchers and engaging with their work, for example through group activities such as ‘Meet the Researcher’?
5. Are students exploring the intellectual, policy-related, practical and ethical challenges associated with current research, and recognising their relevance to professional life more widely?

**Dimension 2: A throughline of research activity is built into each programme**

6. Is there a well designed core sequence of modules, units and/or learning activities through which students steadily build their research skills and understandings, and is this explicit to students?
7. Are students explicitly challenged to make intellectual connections between different elements of their programme?
8. Can students have some flexibility and even take risks with their research-related activities, for example by working towards a Showcase Portfolio for which they can curate their best work?

**Dimension 3: Students make connections across disciplines and out to the world**

9. Is the programme of study structured so that students need to step outside their home discipline(s) and see through at least one other disciplinary lens?
10. Are students required to make explicit connections between disciplinary perspectives, for example by collaborating with students of other disciplines to analyse evidence and issues?
11. Through making interdisciplinary connections, are students challenged to address complex global challenges?

**Dimension 4: Students connect academic learning with workplace learning**

12. Are all students on the programme(s) able to analyse the ways in which their academic learning is relevant to the world of work?
13. Do students have explicit opportunities to prepare for the workplace, for example through meeting alumni, shadowing and work placements and, where appropriate, through critiquing the notions of work and professionalism in society?
14. Can students articulate effectively the skills and knowledge they have developed through their research-related activities and through their wider studies and experiences, and showcase these to future employers?

**Dimension 5: Students learn to produce outputs – assessments directed at an audience**

15. Are some student assessments outward-facing, directed at an audience, thereby enabling them to connect with local and/or wider communities (whether online or face-to-face)?
16. Are student assessments across the programme suitably varied, enabling them to develop a range of skills including expertise in digital practices and communications?
17. Are students required to revisit and use feedback on their tasks, both formative and summative, in order to improve their work?

**Dimension 6: Students connect with each other, across phases and with alumni**

18. Do students have frequent opportunities to meet and participate in collaborative enquiry with one another in diverse groups?
19. Are they building connections with students in other year groups, for example through events or mentoring schemes?
20. Can students meet and learn from diverse alumni and build a strong sense of belonging to an inclusive research and learning community?

*Source: Fung (2017, pp.146-147)*