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From Research-Led Teaching to Research-Based Education

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The material in this handout has been developed over several years with Alan Jenkins, Professor Emeritus, Oxford Brookes University, UK; alanjenkins@brookes.ac.uk. Further and more detailed case studies, including institutional and national examples, references and a list of useful web sites may be found at: www.mickhealey.co.uk/resources. Several of the following case studies are taken from Healey and Jenkins (2009) and Healey *et al*. (2013).

We have found the framework developed by **Griffiths (2004)** effective in supporting staff/faculty to examine both their current courses and institutional policies and practices and in adapting innovations from elsewhere. According to Griffiths teaching can be:

- **Research-led**: where students learn about research findings, the curriculum content is dominated by faculty research interests, and information transmission is the main teaching mode;
- **Research-oriented**: where students learn about research processes, the curriculum emphasises as much the processes by which knowledge is produced as learning knowledge that has been achieved, and faculty try to engender a research ethos through their teaching; or
- **Research-based**: where students learn as researchers, the curriculum is largely designed around inquiry-based activities, and the division of roles between teacher and student is minimised.

A. Context and Conceptual Frameworks

"research and enquiry is a key differentiator at master's level" (*QAA 2013a*)

"Postgraduate study is too late to start; research attributes need to be integrated fully into undergraduate courses" *(Diamond 2010, Research Councils UK)*

"We are all researchers now … Teaching and research are becoming ever more intimately related … In a 'knowledge society' all students – certainly all graduates – have to be researchers. Not only are they engaged in the production of knowledge; they must also be educated to cope with the risks and uncertainties generated by the advance of science." (*Scott 2002, 13*)

"For the students who are the professionals of the future, developing the ability to investigate problems, make judgments on the basis of sound evidence, take decisions on a rational basis, and understand what they are doing and why is vital. Research and inquiry is not just for those who choose to pursue an academic career. It is central to professional life in the twenty-first century." (*Brew 2007, 7*)

"All undergraduate students in *all* higher education institutions should experience learning through, and about, research and inquiry. … We argue, as does much recent US experience, that such curricular experience should and can be mainstreamed for all or many students through a *research-active curriculum*. We argue that this can be achieved through structured interventions at course team, departmental, institutional and national levels" (*Healey and Jenkins, 2009, 3*).

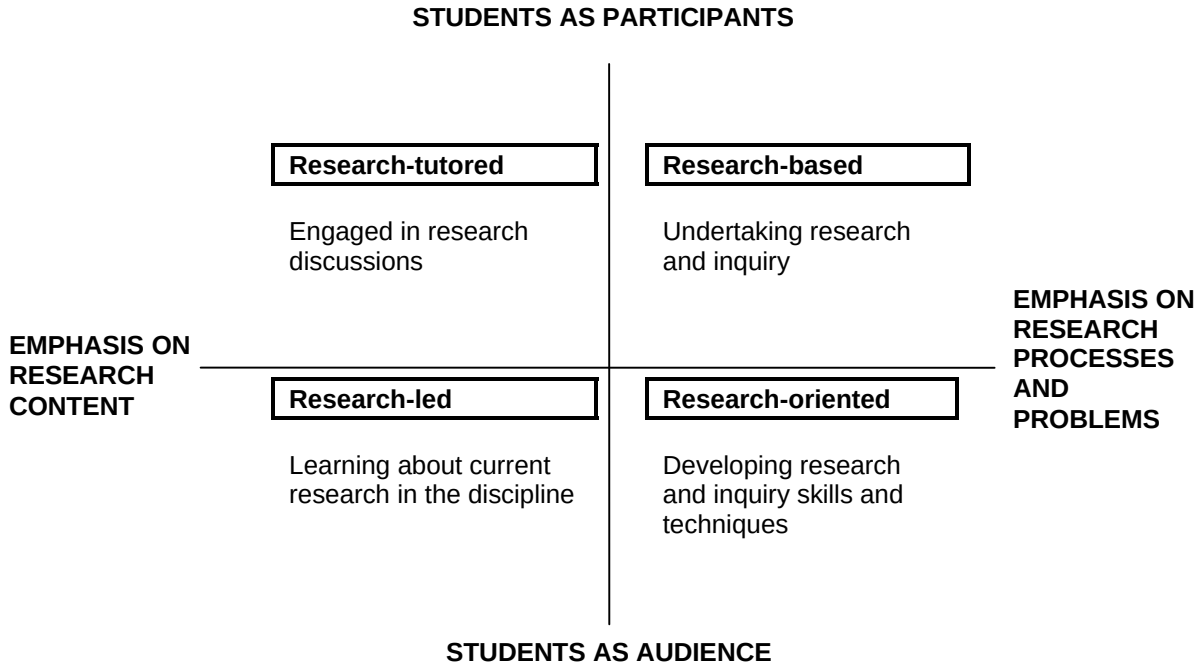
"Our view is that university research often detracts from the quality of teaching. We regret the continuing elevation of research and the systematic neglect of the quality of instruction." (*Pocklington and Tupper 2002, 7 – about Canada*)

"Courses taught by those at the cutting edge of research will necessarily be of higher quality than those taught by those merely using the research results of others – whatever the apparent quality of their style of delivery. …. Furthermore, if teaching is undertaken by researchers the linkage is automatic, even if, as is often the case they are not always teaching about their own narrow research specialism." (*Lee 2004, 9 – with particular reference to geography in UK*)

"Why does every University, thirty-eight of them, public ones, why do they all have to be doing research, teaching and scholarship and struggling to do it in so many areas? Why can't we have Universities that make a conscious decision to specialise in outstanding teaching and scholarship but do very little research? Why can't we have formal affiliations, one specialising in teaching and another research, between our domestic Universities?" (*Brendan Nelson, Minister for Education, Science and Training, Australia, April 2005*)

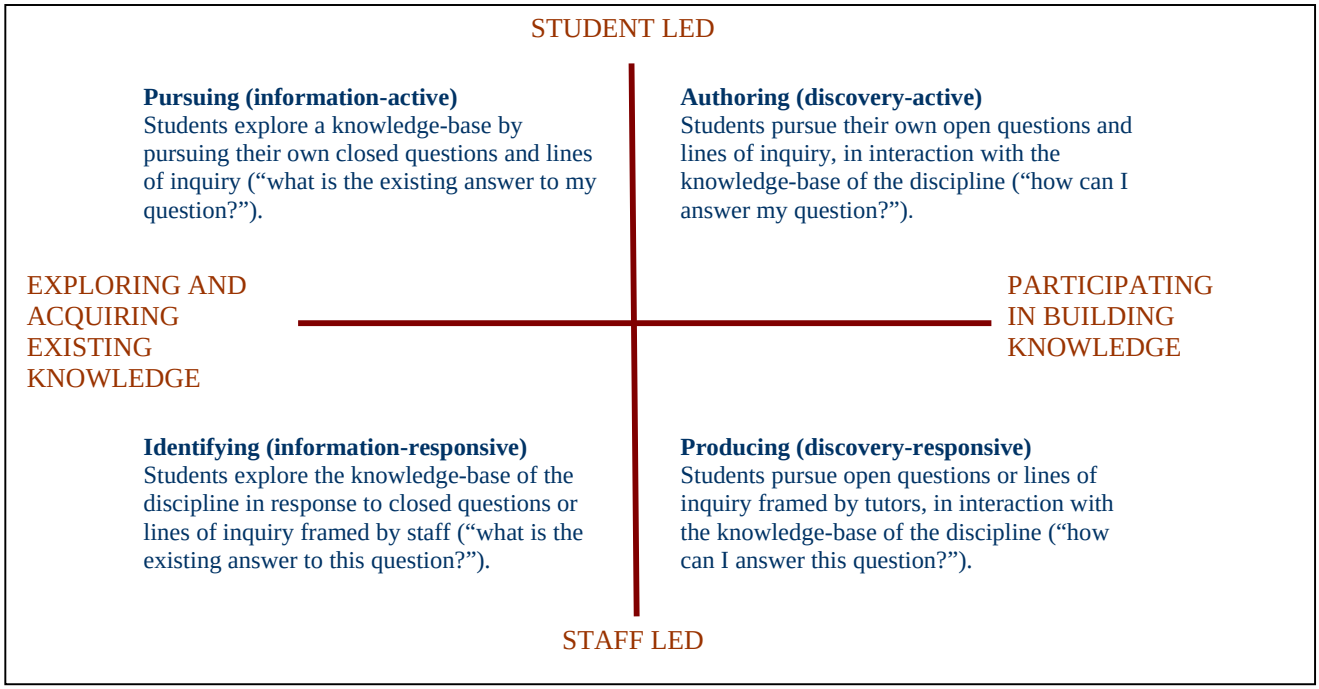
"The academic community in higher education is becoming increasingly fragmented, with arguably the greatest fault line between research and teaching. … through the reinvention of the undergraduate curriculum to focus on student engagement in research and research-type activities, a truly inclusive community of academic practice can be created with consequent benefits to academics, students and support staff." (*Smith and Rust 2011, 115*)

Fig 1 Curriculum design and the research-teaching nexus



Source: Healey and Jenkins (2009, 7), based on Healey (2005, 70)

Fig 2 Inquiry-based learning: a conceptual framework



Based on Levy (2009)

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

The material in this section has been developed over several years with Alan Jenkins, Professor Emeritus, Oxford Brookes University, UK; alanjenkins@brookes.ac.uk. Further and more detailed case studies, including institutional and national examples, references and a list of useful web sites may be found at: www.mickhealey.co.uk/resources.

1.1 Undergraduate research begins in induction at the University of Gloucestershire, UK

In 2007, over 650 students in the Faculty of Education, Humanities and Science undertook discipline-based inquiry projects during induction week. This involved them working in small groups to collect information from the library and in the field, analyse it, present it to tutors in novel ways and receive formative feedback. For example, the human geographers and the sociologists researched the experience of Gloucester residents of 'the Great Flood of 2007'. The biologists and the psychologists investigated primate behaviour at Bristol Zoo. Other faculties in the University are developing their own versions of undergraduate research as part of induction. It has also proved a significant staff development activity both for the many academic tutors involved in designing inquiry-led activities and for the library staff who changed their approach to library induction to support the specific student research projects.

Source: http://insight.glos.ac.uk/tli/resources/toolkit/wal/sustainable/Pages/ActiveLearningInduction.aspx; http://insight.glos.ac.uk/tli/activities/activelearning/Documents/CeAL%20Self-evaluation%20Document.pdf

1.2 Inquiry-based learning introductory course for Social Sciences had a significant impact on students' subsequent performance at McMaster University, Canada

McMaster University has been running a first-year course for Social Sciences based on inquiry since the late 1990s. It is typically taught in groups of no more than 25 students assigned to an instructor, who are subdivided into groups of four or five students. All of the groups have the same curriculum, reading material, process of assessment and goals that are outlined in a detailed compendium. The classes meet for 12 three-hour concurrent sessions. Class time consists of a combination of exercises and tasks for building the students' critical abilities and time for students to

share ideas about their individual inquiries with other students. Students investigate aspects of a broad social science theme, such as 'self-identity', and address a common inquiry question, such as: 'Why do images of ethnicity, race, gender, sexuality, age, class, or abilities help to create aspects of personal and community identity?' Students have to propose their own inquiry question, such as: 'Why do some children apparently become violent after watching violent cartoons while others seem to be unaffected?' They have to justify why the question is important in relation to existing literature. They then investigate the question through a process that involves developing and testing hypotheses using secondary sources. There is strong research evidence of the positive impact of this inquiry course on the subsequent performances of students at McMaster University.

Sources: Justice *et al.* (2002, 2007a, 2007b, 2009); socserv2.mcmaster.ca/Inquiry/CourseOutline.htm. For more recent versions of the course see: http://www.youtube.com/watch?v=i9idE_uCIpc ; http://cte.uwaterloo.ca/research_on_teaching_and_learning/TBRG/OND/2011/Presentations/Vine.pdf

1.3 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 a '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/usser

1.4 1,000 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

1.5 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/research-basedlearning/meet-researcher-linguistics

1.6 High achieving first year students undertake group based research at University of Western Australia

In 2012, 42 high performing students enrolled in the new four year Bachelor of Philosophy Honours degree. The course features an intensive research focus, extensive teamwork and communication skills development, and support for an overseas study experience and on-campus residency. Students may choose a major form any field within arts, commerce, design or science. In the first semester of their first year the students undertake a compulsory unit for credit entitled Undergraduate Learning and Teaching Research Internship Scheme Bachelor of Philosophy undergraduate research training (ULTRIS-BURT). The primary aim is to develop skills in "thinking like a researcher" in the new students, from day one of their university life. In the first run all students conducted research into various aspects of 'sustainable education', wrote up their findings and presented to students and staff at a colloquium held at the University. Initial evaluation shows high levels of learning. This is an adaptation of the ULTRIS scheme which introduces undergraduate students to authentic research outside their chosen discipline in the area of learning and teaching by focusing their research on a teaching and learning issue of identified priority for the University.

Source: http://www.teachingandlearning.uwa.edu.au/teaching/management-framework/eso/undergraduate-research; http://www.studyat.uwa.edu.au/courses-and-careers/undergraduate/phil-honours

1.7 Grand Challenges 2013: a researcher led programme for first year undergraduates at University of Exeter, UK

This programme provides first year students with a researcher led 11-day educational experience at the end of the academic year. Students produce solutions and ideas to tackle some of the key dilemmas of the 21st Century, like climate change, ageing, ethical banking, child health and international security. The programme includes a cultural, social and sporting festival on campus during the middle weekend.

Central to the programme are twelve interdisciplinary 21st century dilemmas. Students work in cross-disciplinary groups to address significant cultural, social, economic and/or environmental issues. Divided into small groups facilitated by a postgraduate (PG) inquiry group facilitator, students research key questions and produce negotiated outputs which are communicated to wider audiences. Examples include writing a policy paper, U-tube videos, debates, awareness campaigns, myth buster pamphlets, social media discussions and dramatic presentations.

Four key principles which relate to research informed education underpin the dilemmas:

Research led

Exeter has a tradition of introducing undergraduates to research skills and ideas and this is embedded in the Strategy for research led education. The 21st century dilemmas provide a powerful focus for teaching and learning through research. Senior Academic Champions with a national or international research profile take the lead and recruit well known external champions to work with them. Together with other academics and PG students they ensure the rigour and research relevance of the work.

Interdisciplinarity
Each dilemma builds on interdisciplinary research being undertaken at the University. Students are given insights into this research and use concepts and approaches to develop skills which transcend disciplinary boundaries. They should be able to transfer some of their new research knowledge and skills into their University programme during subsequent years.

Inquiry based learning
Ensuring that students have an intrinsic motivation to engage is a challenge at the end of the summer term; consequently dilemmas are designed around active approaches used by researchers. With support, students:

- actively set their own goals;
- take part in research like activities to gain knowledge and skills; and
- are responsible for communicating high quality outputs at the end of the dilemma.

Education for employability
Employability related master classes and research-like employability related skills are embedded into the programme. Opportunities to reflect on these are integral. A significant link has been made with the Exeter Award and several employer led events take place. Students who show the greatest commitment and innovative thinking are awarded places at the Battle of Ideas 2013 and, for a select few, a chance to attend the One Young World Summit 2013 . At both of these events they will have opportunities to work with internationally reknown thinkers and researchers.

Sources: Correspondence with Sue Burkill (Sue.Burkill@exeter.ac.uk); Burkill (2015) http://www.exeter.ac.uk/grandchallenges/aboutgrandchallenges/; Kay, J (2013)

1.8 Writing history – a first-year course at UCL, UK

"There is a really big issue in the transition from school to university, and it's getting bigger," Adam Smith, talking about the difficulty students face in adapting to undergraduate essay-writing.

The problem, according to Smith, stems from changes made to the A-Level curriculum over the past 10-15 years. As mark schemes for A-Level essays become more prescriptive, so students grow used to being spoon-fed essay plans. In some cases, that has left them unprepared to deal with the rigours of a university humanities programme.

Writing History is linked to the topics that students are studying in their other modules. The course starts with a few introductory lectures that introduce academic writing and research. After that, small groups of three or four students are matched to tutors who have expertise in a subject the students are currently studying. They are set practical writing exercises and discuss them with each other. It's an opportunity to build confidence and ask questions in a situation that isn't intimidating. It also helps them develop the habit of peer assessment.

All tutors have some leeway in designing their own tasks. What they have in common is the use of small writing assignments and group discussion. For example, in Smith's group in advance of the first tutorial session, he sets a question relevant to his specialism. Students are asked to email their 150-word responses to him and the other students in the group. Then, in the tutorial, they pick them apart and discuss each other's. Why have they chosen those words? Have they communicated the idea they wanted to get across? Other tasks include writing a synopsis of a book or condensing an argument in a short paragraph. He also presents sentences taken from different parts of an essay and asks them to consider where they may have come from – the intro, the main body or conclusion. Every History student writes their first essay in the context of this course. They each get to produce a first draft that they can discuss with their tutor. They then get feedback before producing a final draft.

In its first year, the course was better attended and more popular than any other compulsory course, with 100 percent of students agreeing the course was 'good' or 'very good'. Every feedback respondent also said they'd benefitted from small group teaching and staff agree that student essays have improved as a result.

Sources: http://www.ucl.ac.uk/teaching-learning/case-studies-news/key-skills-ppd/adam-smith-how-to-improve-student-essay-writing; http://adamipsmith.com/2013/06/04/how-to-write-a-history-essay/; https://www.youtube.com/watch?v=-C1PVRp1xII

1.9 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/

1.10 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/

1.11 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)

C. Final year and capstone projects

See also: 2013 *Developing and enhancing undergraduate final year projects and dissertations*. York: HE Academy. (Healey M, Lannin L, Stibbe A and Derounian J) 93pp
http://www.heacademy.ac.uk/projects/detail/ntfs/ntfsproject_Gloucestershire10

2.1 Engaging students in applied research through a community sports development consultancy project at University of Central Lancashire, UK

The final year Community Sports Development module acts as a capstone module for Sports Coaching students. This module is an optional module which is taken in addition to the honours dissertation. Students work as a project team through a consultancy brief with a partner agency and recommend strategies that can be employed to support community development through community sport and coaching initiatives. There are normally 8-12 consultancy briefs divided up among the 40-50 students, with students creating their own consultancy teams. Examples of consultancy projects include: a) A "health check" of football refereeing in Blackburn; b) Community Sport and Crime Reduction; and c) Community Sport ("Street Dance"). The emphasis is upon the students creating professional working relationships with the client organisations in order to carry out primary research that is directed by the clients and supported by the Academic staff at the University. Students are expected to hold regular review meetings with the clients, carry out interviews with relevant stakeholders; use secondary research to help analyse their findings; and present their work and recommendations to the organisation through the staging of a mini–conference, where all the partner groups are invited. Representatives from agencies provide the feedback on students' work, judging on the content, feasibility of solutions, and competency in conducting research.

Source: //resources.glos.ac.uk/ceal/resources/casestudiesactivelearning/undergraduate/index.cfm

2.2 Modelling the research experience: Tourism students' virtual conference at Universities of Lincoln and Wolverhampton, UK

In May every year, final-year Tourism students at the Universities of Lincoln and Wolverhampton participate together in a live virtual conference, as part of their final-level assessment. A conference is a useful vehicle for extending insight into the process and practice of knowledge creation and dissemination and for students to participate as, in effect, research disseminators. Information technology has made it possible: during the specified time frame of one week, students across two campuses can come together at times of their choosing to participate in a joint effort to

disseminate research findings and engage in dialogue about their research. Feedback from them has been very positive and encouraging. Two qualified web designers built the site and have been on hand to deal with technical issues. Teaching staff have provided support for the conference throughout. Students submit a full conference paper, but it is only a summary discussion paper that appears on the conference website. Each student is also required to post a comment on another conference paper, in true conference dialogue tradition.
Sources: www.tsvc.lincoln.ac.uk;

2.3 Language students work in teams on international market research projects at Leeds Metropolitan University, UK

For almost 15 years all the final-year undergraduates on language degrees at Leeds Metropolitan University work in teams of four over a full year to undertake international market research projects on behalf of local businesses, following project briefs prepared for them by the managers in those businesses. The students practise the whole range of skills they have developed on their course (applied languages, team-working, time management, research, project management, data analysis, report-writing, presenting recommendations and so on) in a real-world environment based on genuine commercial needs and products. The students appreciate that they are not working on a case study but with actual products and professionals who teach them about expectations in a professional environment. Over the years, those products have included fashion jewellery, specialist woven fabrics, language services, bathroom equipment and even high-speed, crash-proof shutter doors. Students are particularly fascinated by the company or factory tours as, for many of them, it will be the first time they have ever seen behind the facade of a business. The employers also prize the experience as they get valuable research undertaken that can assist them with their strategic development of international markets.

Sources: Webb (2008; 2012)

2.4 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

2.5 Biology start up business final year project, University of Durham, UK

Biology Enterprise is a collaborative venture between Durham Business School and the School of Biological and Biomedical Sciences. This elective module for final year undergraduate students in the School of Biological and Biomedical Sciences aims to introduce science students to the key processes of business start-up and enhance their enterprising skills and behaviours. The module is project-orientated with self-selecting groups of students who generate an idea for a business opportunity that is based on a scientific discovery. Students use their knowledge and understanding of science to develop and research their idea into a technology that can be readily commercialised e.g. a diabetes breath tester, a biodegradable chewing gum. In parallel, the Business School teaches students the

necessary skills and knowledge required to develop their idea into a successful business. This course offers science undergraduates an alternative to the traditional laboratory-based project and is useful for those seeking employment in business and commerce.

Sources: http://www.bioscience.heacademy.ac.uk/events/dur05.aspx
http://www.dur.ac.uk/biosciences/undergraduate/courses/content/level3/lab_project_enterprise_schools/;
http://www.bioscience.heacademy.ac.uk/journal/vol11/beej-11-r2.aspx
http://www.bioscience.heacademy.ac.uk/ftp/events/york05/cowie.pdf

2.6 Senior Capstone at Portland State University, US

During the final year each undergraduate student is required to participate in a Senior Capstone, the culmination of the University Studies program. The Senior Capstone is a community-based learning experience that:

- Provides an opportunity for students to apply the expertise they have learned in their major to real issues and problems in the community;
- Enhances students ability to work in a team context necessitating collaboration with persons from different fields of specialization;
- Encourages students to become actively involved in this community.

Each student works with a team of students and faculty. Each Senior Capstone must result in some form of summation, closing project, or final product that puts closure to the students' experience. Senior Capstones vary in length ranging from one term to three terms, depending on the specific nature of the Capstone.

Sources: www.pdx.edu/unst/senior-capstone;
www.oirp.pdx.edu/portweb/published_pages/prototype/themes/cp/capstone/

2.7 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.

2.8 Involving Students in Interdisciplinary Interactive Media Consultancy Projects at Miami University, Ohio, US

Interactive Media Studies at Miami University is an interdisciplinary programme (including Computer Science, Engineering, MIS, English, Marketing, Graphic Design, Education, etc.) that brings together students and faculty to investigate how interactive media informs and transforms their disciplinary perspective. The programme has been running since 1996 and uses problem-based learning and team-oriented projects to help students to learn how to apply their theoretical knowledge to innovative digital solutions for a paying client. About 100 students a year take the programme. The students work in groups of up to 20. The students themselves decide how to divide up tasks; typically there are groups undertaking development, design and marketing. The programmes are team taught with the last two weeks spent on de-briefing and talking about what they've learnt. The students are typically in class four hours a week, but spend many more hours, for example visiting clients, undertaking research or doing user testing. They make a presentation to their client at the end of the project. Commercial companies are charged $20,000 per project paid on delivery; non-profit organisations and charities are typically charged c$5,000. They found the client did not take it as seriously when no charge was made. From the client's perspective, they get out of the box thinking that they would never obtain from a consultant firm. The clients typically end up with something that far exceeds

their expectations. The students find it surprising and challenging to manage the changes which commonly occur during the development stage of the project.

Sources: Interview with Glenn Platt 14 November 2007; http://student.sba.muohio.edu/ims/

2.9 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 staring 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 or email d.i.lewis@leeds.ac.uk

D. 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) 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 Using undergraduates to evaluate student experiences of teaching and learning in the Sociology Department, University of Warwick, UK

In the Department of Sociology at the University of Warwick, selected second- and third-year Sociology students led an evaluation of their peers' experiences of teaching and learning. They used a variety of social research methods – including focus groups, interviews and participant observation – to explore the learning experiences of their peers. The results were widely discussed within the department, and at a department away-day, and have led to students being more involved in department academic debates. Clearly it is more transferable to those departments and disciplines such as Sociology, Education, Psychology and Management, where students developing research skills 'match' the research focus.

Further information: Hughes (2005)

3.3 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/

3.5 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)

3.6 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

3.7 Engaging students in research into teaching and learning at the University of Western Australia and University of Exeter

The Undergraduate Learning and Teaching Research Internship Scheme (ULTRIS) was conceived at The University of Western Australia (UWA) to introduce undergraduate students to authentic research outside their chosen discipline. By focusing their research on a teaching and learning issue of identified priority for the University, students are able to make significant contributions to the understanding of the problem and provide insights to inform future changes in policy and practice. Beyond the benefits to the institution and the individual students, this model of undergraduate research heralds an opportunity for research into teaching and learning to gain acceptance and interest amongst a new and previously uninvolved cohort of investigators.

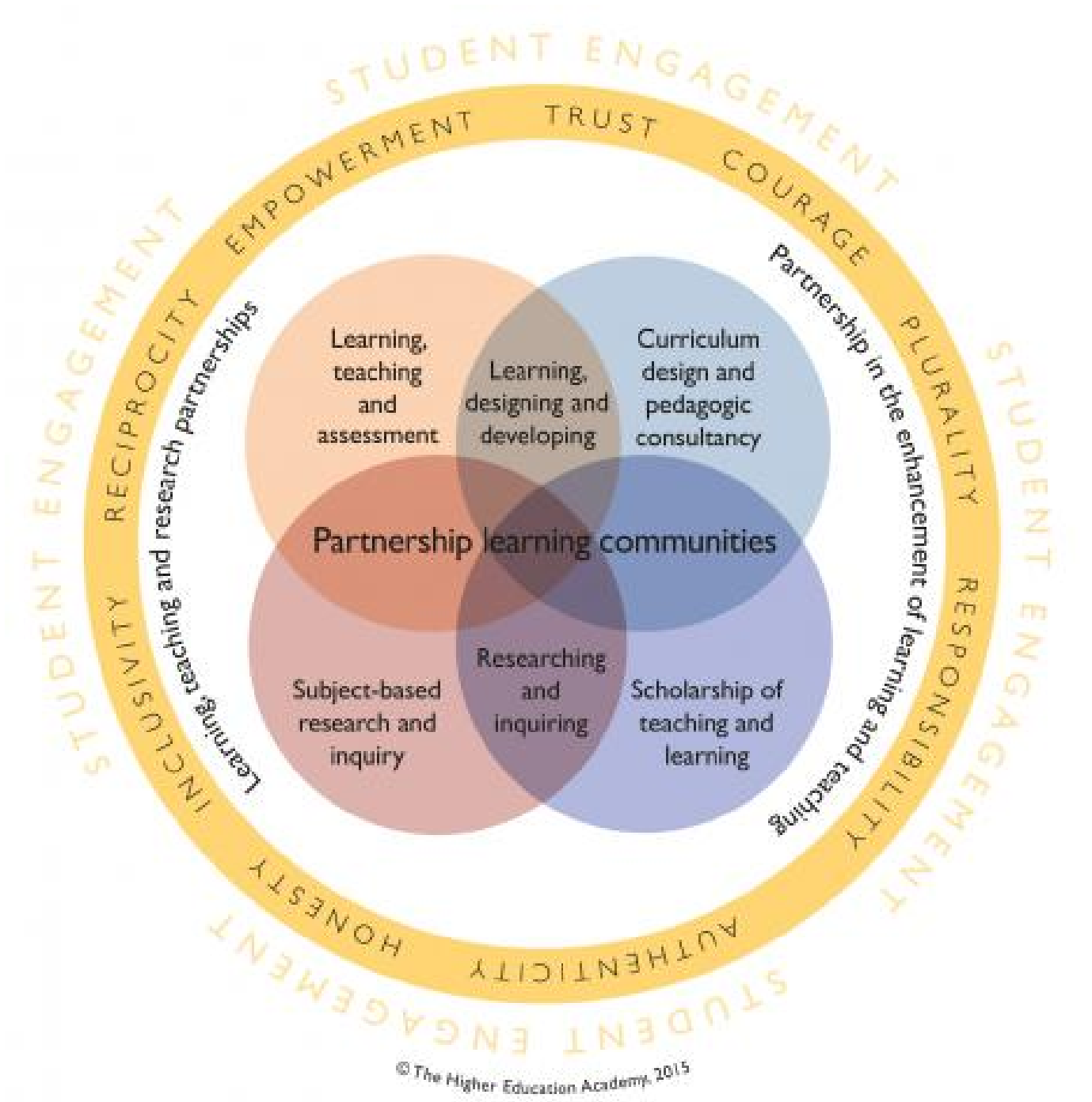
At the **University of Exeter** students are engaged as partners in shaping and leading their own educational experiences through their **'students as change agents'** initiative. The key concept is that students themselves take responsibility for bringing about change, based on their own research on aspects of learning and teaching. The approach enables students to be actively engaged with the processes of change, often taking on a leadership role. They are engaged deeply with the institution and their subject areas, and the focus and direction is, to a greater extent, decided by students. The most important aspect is the focus on research, and building change on evidence-based foundations.

Students from across the university have contributed to this initiative, carrying out a series of research projects on their learning and teaching environment, selecting concerns raised through student-staff liaison committees (SSLCs), and providing recommendations and solutions to improve their experience. A small amount of funding was made available from the University's learning and teaching budget to support this initiative. Students worked as apprentice researchers; their research methods included focus groups, informal interviews and questionnaire surveys. Outcomes were presented at a student-staff conference, which resulted in institutional engagement with key research findings. Each small project has also been captured through a case study. Student research has driven organisational change, contributed to student engagement in shifts of policy and practice within the University, and supported students' graduate skills in the areas of research, project management and presentation of outcomes, leadership and understanding organisational development.

Further information: Partridge and Sandover (2010); Kay *et al*. (2010); Dunne and Zandstra (2011)

For many more case studies of students as change agents see: www.mickhealey.co.uk/resources

Fig 3. Students as partners in learning and teaching in higher education: An overview model



Source: HE Academy (2015) Based on: Healey, M., Flint, A. and Harrington, K. (2014) *Engagement through partnership: students as partners in learning and teaching in higher education.* York: HE Academy p.25.

The model is discussed in:

Healey, M., Flint, A. and Harrington, K. (2016) Students as partners: Reflections on a conceptual model, *Teaching and Learning Inquiry* 4(2)