Relating Research and Teaching: comparing experiences and beliefs

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Abstract - **The relationship between research and teaching has possible benefits and inherent tensions. It is a recurrent topic of discussion by faculty including engineering educators. Exploring a potentially beneficial relationship and is of interest and possible value to engineering faculty, our students, and our stakeholders. Institutions and departments have developed a range of approaches including research-led, research informed, or just plain scholarly. This paper examines the relationship between research and teaching in the undergraduate curriculum. It compares and contrasts evidence of the beliefs and experiences of the engineering faculty and the engineering student. It presents and analyses the result of surveys which gathered qualitative and qualitative data to explore the inter-relationship of research and teaching; in the curriculum; and as it is delivered and experienced in the lab, seminar room and lecture hall. This research builds on existing work developed in a preliminary study which examined ways in which synergies between research and teaching could be achieved, particularly in the 'hard/applied' areas of the curriculum. It analyses data from the 'research-intensive' and the 'teaching-intensive' perspective.**

Index Terms - disciplinary differences, research-led teaching, research-teaching nexus, scholarship of teaching and learning.

INTRODUCTION

A primary objective of this paper is to use evidence of current educational practices to situate the arguments associated with the debate on the relationship between research and teaching within the engineering education community. It is intended by providing some evidence of beliefs and experiences from practice within this community, that the field will be further explored, and therefore become better understood.

As well as understanding current practice, there is some opportunity to consider the potential value of developing systematic approaches to linking research and teaching in the engineering disciplines. Research practice and the student experience have all been affected by recent rapid changes in the use of technology. Students' prior experiences, and their expectations, along with those of stakeholders have changed and will continue to do so. Furthermore it is important that university educators acknowledge of the role of personal learning for life, and the realities of informal learning. These changes to the learning landscape should urge us to reconsider the potential value of linking research and learning, and providing that analysis of an interpretation which is of particular value to the engineering graduate.

This paper presents some background to the literature which informed the motivation for the research. It then presents an account of the research which has been conducted, followed by an analysis of the findings followed by conclusions and suggestions for future work.

BACKGROUND

The view that there is a relationship between research and teaching is not a new one. As Lewis Elton points out, in 1807, Humboldt observed, "In universities, learning should not be [defined] in terms of the passing on of well established knowledge, but always in terms of not yet completely solved problems." [1]. Elton was contributing to the more recent debate, which has trickled its way down into institutional strategies and policies today. The current interest is in the possible positive relationship between research and teaching. It owes much to the work on Ernest Boyer. Boyer, on behalf of the Carnegie Foundation looked at the future of undergraduate education [2]. When the Boyer Report was initially published, the messages which came from its findings reverberated around Higher Education and its associated communities. Its follow up report [3] was to ensure that the reverberation continued. Governmental policies, funding directives, institutional strategies and classroom tactics appeared to some extent to be influenced by the study.

The focus of the Boyer Report was purposefully concerned with undergraduate education in research-intensive universities. However it was not difficult for readers to discern that the insight of the findings were relevant to the undergraduate curriculum irrespective of whether the teachers and institution were working at the cutting edge of current research.

The initial community which debated and researched the relationship between teaching and research tended to include many who were educational theorists and practitioners whose primary interest and motivation was in the area of educational development. Mostly, their findings were reported in specialized educational communities. Such communities belong in what Biglan, considering the evidence for disciplinary differences [4], typifies as the world of soft, pure/soft, applied fields of study. It is a world predominantly concerned with social science, arts and humanities fields of study.

Recently work on the relationship between research and teaching has continued in their specialist communities. There has been some participation from faculty who are heavily engaged in teaching. Some of those participants are also active researchers in their chosen subject discipline; others are teachers who are active scholars in the teaching of their discipline, rather than front-line researchers. Some participants have emerged from the 'hard,pure/hard, applied' academic communities, but the 'soft,pure/soft,applied' perspective continues to predominate.

Work in the UK has been led by Jenkins and Healey who have produced a substantial body of materials [5-12]. Part of their contribution has been through conventional academic publications, but they have also worked in conjunction with the UK Higher Education Academy to produce a large volume of publications designed to act as primers and implementation guides aimed at faculty at all levels. Many of the guides speak from a general perspective, whilst the discipline specific materials coming from geography have predominantly more resonance with the social science perspective. Healey has developed a framework to guide the development of the relationship between research and teaching in the curriculum which is rather different to the four scholarships of research and their application to teaching which was proposed by Boyer (see figure 1).

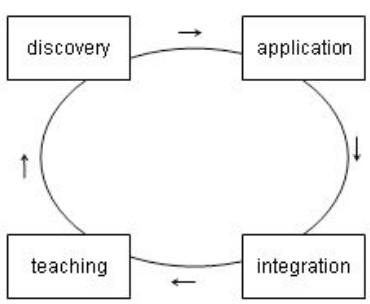

FIGURE 1 REPRESENTING BOYER'S FOUR SCHOLARSHIPS

Boyer is clear in his writing to suggest that by focusing on scholarship, his work is very much concerned with teaching, for example "[Teaching is not a] routine function, tacked on, something almost anyone can do. When defined as scholarship, teaching both educates and entices future scholars" [13]

The analysis presented by Boyer was subjected to some criticism. Many universities are not research intensive and many university teachers are not active researchers. There has been some feeling that that the Boyer perspective draws people towards a simplistic model where the relationship between research and teaching is typified as 'I research, I teach my specialism and I supervise project students, so my teaching is research-led'. Drives for research excellence and its associated exclusivity have had an impact across higher education which seems to have spilled over into the discussion of the relationship between research and teaching. At the same time however, for academics who are working at the bleeding edge of research, seeing the full picture of the cycle of scholarship offers a way in which they can understand how their research can be related to their teaching. Perhaps this matters more in the quantitative world of hard science and engineering subjects than it does in more qualitative world of social sciences, arts and humanities.

Working from the curriculum, Healey effectively sidesteps the issue of whether the individuals concerned are actually active researchers. In his exemplar, Healey draws a distinction between students being participants in research activities, and students being audience to research activities, and offers a conceptualization which can be used as an aid to curriculum design. A diagram representing Healey's four approaches is shown as Figure 2 below.

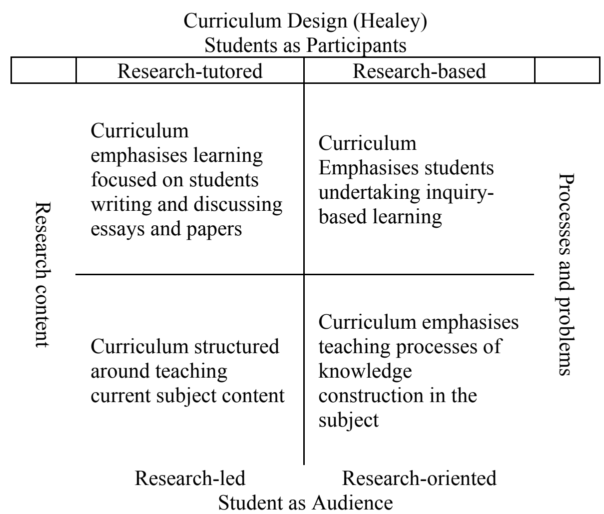

FIGURE 2 CURRICULUM DESIGN RELATING TEACHING AND RESEARCH
ADAPTED FROM HEALEY [10]

It has been the experience of the authors that when working with engineering academics, examples drawn from our own disciplines are most useful. In his study of disciplinary differences Biglan points to fundamental differences in the nature of scholarly practice and academic discourse between disciplines. Lucas and Turner when considering the relationship between research and teaching do report on perceptions of academics from many of the hard disciplines [14], however their sample is small, and interviews are with early career researchers rather than with established academics.

The concern of our educational community is engineering education. The authors had encountered some difficulty in communicating the conceptual model proposed by Healey to academics in their institutions, yet it was clear after some discussion that the same academics did have some clear ideas about the ways in which they might go about relating research and teaching within their areas of the curriculum. This understanding reflects a view which is expressed more formally by Neumann et al [15] in some relatively recent work which revisits Biglan's territory of the hard versus soft, and pure versus applied fields of study and specifically looks at disciplinary differences in teaching. They state that: "a sound understanding of key aspects of teaching and learning must depend on the recognition of the distinctive features of different knowledge domains and their social mileiux".

It was a desire to obtain a clear understanding of how academics actively relate teaching and research and thereby identify models of usage which better fit with the engineering perspective which motivated the work which is presented below.

APPROACH

Academics from a range of engineering disciplines were asked to provide explanations of their understanding of the ways in which they could, or could not find a means of relating teaching and research in their usual undergraduate teaching tasks. Subjects were initially drawn from to UK institutions, one research-intensive, and the other teaching intensive. An initial study was conducted considering subjects drawn from the computing disciplines [16]. This findings reported in this paper extend the survey area to encompass broader engineering fields of study.

A desk survey of all modules offered in the undergraduate curriculum was undertaken. Module descriptions and stated learning outcomes were evaluated against Healey's descriptors, which were then used to build a profile of the curriculum. Faculty members were surveyed to provide accounts of the ways in which they were or were not able to find a means of relating (their) research to teaching. Two follow up surveys were then designed, one for students and one for faculty. The initial versions use vocabulary which is pitched at UK academic practice. A further version which is more international is currently being developed in order to extend the scope of future studies.

In the original survey, views were elicited from two universities. The first is a member of the Russell Group of research-led universities. It has ten schools in the faculty of engineering, science and mathematics, all of which have attained the highest possible scores in national research ratings. All undergraduate students attend in full-time mode at the main university campus, many take a four-year undergraduate masters degree, although the exact proportion varies according to the job market and across the fields of study in engineering, science and mathematics. The university has a large number of post-graduate research students and a significant proportion of its total income is derived from research.

The second institution is a teaching-intensive post-1992 university where the vast majority of the institution's income is derived from teaching; significant income is also earned from technical consultancies to businesses. Its undergraduates study a range of vocationally oriented modern style degrees. Students may be full-time or part time; there is an opportunity for some students to study two-year foundation degrees. The vast majority of students take BSc (honours) degrees which typically include a one-year industrial placement between the second year and final year. Academics engage in some disciplinary research, consultancy and scholarly activities, and there are small numbers of post-graduate research students.

Each module was analysed to determine whether any of the four approaches described by Healey were being utilised. In some cases the module description was explicit in identifying an approach which came from a research perspective. In other cases it was necessary to associate the description provided with the broad definitions offered by Healey.

At the same time, academics teaching on the degree programmes were surveyed in order to explore their perceptions of the relationship between research and teaching in their educational practices. They were asked to evaluate which of the four approaches identified by Healey; research-tutored; research-based; research-led; research-oriented; they typically employed in their teaching. It was also used and to identify any other approaches they adopted, and their preferences for describing their approaches. Finally, they were also asked to comment on the possible strengths or gains from the relationship between research and teaching, and whether they considered any area of the curriculum was not suitable for such an approach.

The findings are summarised on a year-by-year basis below. It may be worth reminding readers that the UK higher education system is one where students typically select and specialise in their final degree outcome from year 1. Across the sector as a whole three-year undergraduate degrees are fractionally more widespread, although in research intensive universities four-year undergraduate masters degrees are in the majority and account for approximately 60% of the graduations.

Entire degree courses are referred to as programmes, individual courses of study within the programme are referred to as modules. For the basis of this analysis degrees in the engineering domain are those which consist of sets of coherent modules which students are required to pass before they can progress to the next year of study. There will typically be core modules which are compulsory, and optional modules which students may select to achieve their preferred level of specialisation.

Year 1

Initially, students are predominantly taught in large cohorts across degree specialisms, although this will vary with the range of engineering options offered at any institution. Students arrive with heterogeneous skills, knowledge and understanding. Large lecture classes are typically used to establish a common base-level of knowledge and understanding. Some modules introduce students to concepts of professional practice across the engineering disciplines. Students are paired with lab partners for practical activities where acquisition of knowledge and understanding is integrated with psycho-motor skills. Students will also attend supervision classes (technical education, which may be administered to small groups), group tutorials (may mix pastoral and technical education). Across the modules and academic's surveyed educational objectives which offered opportunities for research associated teaching included providing students with the opportunity to:

- "Think like an engineer"
- Work to examples which had (for the learner at least) unknown outcomes.
- Examine/consider examples of current research in class
- Be tutored/instructed by a research who provided insight into their passion/motivation

Some colleagues commented that it was not appropriate or feasible at this level to incorporate current research into their teaching. An example of good practice was offered by a colleague who had given students an opportunity to explore current research agendas by setting a task whereby they were asked to work in groups to prepare a short presentation suitable for school children which introduced them to an exciting research area in the field of their degree specialism. The introduction of academic formalisms such as technical writing also serve to establish ground rules for research practice which can be revisited in future years.

Year 2

These modules are used to consolidate basic skills, knowledge understanding. Again they may be addressed through large lecture classes. Objectives include to prepare students for independent work. Research based approaches include teaching research methods; writing exercises which incorporate peer reviewing. Some colleagues offer reading courses, and there is some small group teaching. At this level students are required to mimic the behaviour of researchers, there is greater homogeneity because the students are progressing towards becoming engineers.

Year 3 – final year bachelors

At this level, there is an increase in small group teaching. Students are considered to have sufficient level of basic understanding to address independent study, although it was observed that not all students are equal in this regard. Many academic objectives are seen to address Bloom's higher-level cognitive skills. Typical tasks reported included preparing research style papers, and following reading courses. Practical activities incorporate design and build, and project tasks are set where according to the judgement of the project supervisor students undertake more of less open ended activities, some of which offer the opportunity to make new discoveries.

Year 4 undergraduate masters

At this level there was much more evidence of explicit/intentional research links. Students were reported as having to produce small demonstration pieces. Writing incorporated typical research activities including peer review, revision and presentation (typically as a poster). In some instances students were encouraged to participate in research group activities such as group seminars.

Other Activities

In addition to the opportunities within the formal curriculum students also have opportunities to experience the relationship between teaching and research by means of informal learning which can take place on internships. It is common for research-intensive universities to offer internships, but various large companies who offer places in a research and development context which are open to students irrespective of the nature of their institution also make such opportunities available. Such activity is not specifically associated with any particular level of study, although it is most often taken towards the culmination of the period of study. The value of such internships has been recognised by EPSRC who have funded schemes at some UK universities.

Returning to Healey's matrix it is possible to repopulate the quartiles with examples which are more explicitly relevant to the engineering educator. An initial exemplar is provided in figure 3 below.

Students as Participants

Research content	Research-tutored	Research-based	Processes and problems
	e.g.: classic tutorial structure – typically small group supervisions in the engineering disciplines Supervision class where students are taken through recent publication(s) and are invited to discuss/debate their understanding of the activity. Possible at each level of study, but for organisational/management reasons may only apply in particular years of study.	***e.g.: authentic research activities, inquiry/enquiry based learning*** Students are given a task which requires them to use and develop skills (practice and understanding) which are equivalent to those used in authentic research. May be practiced at any level of study, but may be more typically found at advanced levels	
	e.g.: curriculum follows current research Most typically advanced level options. Can also be a component of teaching at any level, where students are exposed to state of the art research concepts	***e.g.: teaching processes of knowledge construction*** Typically found in capstone courses where students undertake some research activity, individually or as a group. Students at less advanced levels may practice this as part of research based activities	
	Research-led	Research-oriented	

Student as Audience

FIGURE 3- REPOPULATING HEALEY'S MATRIX WITH ENGINEERING EXAMPLES

DISCUSSION

Response to the survey questions varied according to the type of teaching which was taking place. Undergraduates and study a range of topics which can require them to develop knowledge, skills and understandings which are associated with (in different instances) are associated with both science and engineering. In some cases they are also required to work in social science areas. Healey has pointed out that the ways in which research and teaching can be interlinked will vary according to discipline; the complex nature of the curriculum across the engineering disciplines makes this a rather complicated instance.

The survey demonstrated that activities which inter-relate research and teaching exist in at least both examples of a research-intensive and teaching-intensive institution. In this instance, existing and state of the art discipline based research plays a strong role in educational practices outside of a research-intensive academic departments. Anecdotal evidence would suggest that this is to be found elsewhere, however wider data collection is necessary to develop a more authoritative picture across the sector.

Colleagues at both institutions expressed a range of understandings of what was meant by Healey's four terms. Generally there was a belief that developing the relationship was more easily attained in the third and fourth year. At the research-intensive institutions many colleagues responded that of course they related research and teaching – by virtue of their dual roles.

It may be that active curriculum development could be undertaken to enable more widespread linking of teaching and research during the first two year's of study. In the teaching-intensive institution the university explicitly provided a course of study for academics which explored the relationship between research and teaching. Colleagues have commented that students are ill equipped in later years to undertake more intellectually demanding tasks of analysis and critical thinking. Accordingly new activities can be designed for first year-work on these skills at a basic level. In one of the institutions such a development is planned this year for the module which addresses professional skills. The problem however in engineering is often that the early years are already full with technical and mathematical content which is needed to enable students to undertake higher level technical activities in the latter part of their study.

Examples where students experienced teaching approaches which were drawn from a research perspective tended to be participative rather than didactic, and more highly motivating.

If we are looking at ways in which to bring about change in the student experience because we believe that it will be enhanced by a greater inter-relationship between research and teaching it may even mean that we will need to consider changing the research balance of academics so that it aligns to teaching needs.

Healey's model excludes the scholarship of teaching and learning from the teaching research nexus, however we believe that engineering education is of itself a field of study within the discipline. Colleagues cited examples of how they brought their research into this area into their teaching, and indeed how they made this aspect of their teaching explicit to their students. This approach can be particularly useful when bringing about change in and established curriculum as a means of alerting students to the meta-objectives of the activities, and gaining their trust and confidence in the face of introducing them to what may be new methods of learning.

Discovery	**Application**
Core to enquiry based curriculum Natural in lab based courses Final year projects Internships	Proxy activities in follow on courses Proxy discovery in lab classes Apply previously learnt skills, knowledge, understanding Internships Final year options Masters curriculum
Capstone modules Final year projects/dissertations Synoptic assessments Design classes	Professional issues Skills modules Peer instruction Small group teaching methods
Integration	**Teaching**

FIGURE 4: ALLOCATING ACTIVITIES TO BOYER'S SCHOLARSHIPS

CONCLUSIONS, REFLECTIONS, FUTURE WORK

From the surveys it has been possible to gather evidence of activities which create a link between research and teaching at each year of study. An attempt has been made to offer examples of typical practice which fit within the concept of curriculum mapping which was developed by Healey. Exemplar activities which are typical of teaching within engineering disciplines have been found and are offered as explanations to the meanings of the terms research-tutored, research-based, research-led and research-oriented. It has been noted that some colleagues had difficulties attributing their activities to the categories provided by Healey, but that with discussion they were more easily able to associate activities with the four stages of scholarship which Boyer originally proposed. It has also been possible to associate typical teaching activities which seek to integrate research and teaching with each stage of Boyer's four scholarships.

It may be that there is an issue in looking at the relationship between research and teaching in the engineering disciplines because engineering is fundamentally a pragmatic activity. This perhaps reflects a disciplinary difference which exists between scientists and engineers, since some engineering education is inevitably at the cusp between science and engineering. However good engineers adopt rigorous practices which are just those practices which are needed by good researchers.

What it patently true is that academics in engineering disciplines are not typically social scientists, although they may sometimes use methods which were developed in the social science. However the differences between the hard/soft and pure/applied perspectives may serve to make the literature which deals with the relationship between teaching and research more difficult to access, or alien to the engineering mindset.

For departments seeking to make change in the educational arena, probably a whole curriculum approach is needed. Some will choose to go towards enquiry based learning, there are notable examples in the Danish engineering universities where this has been adopted. Whole institution approaches to addressing the methods most suitable to integrate research and teaching are perhaps unlikely to succeed because of disciplinary differences. It would be advantageous if this were borne in mind in courses which address academic practice for new faculty.

This study points to the benefit which can be accrued from gaining more evidence of current practice. There are opportunities to compare practice across different education systems from learners as well as from academics.

Meanwhile, on the horizon, students are arriving at university with skills sets crafted by complete exposure to the information age. They face a future where they may well be employed in jobs which do not yet exist, and where the half-life of information appears to be shortening by the minute. Informal education is increasingly important, and all stakeholders value the ability to learn in a self-sustaining manner. Adopting curricular which incorporate research skills, and an understanding of how the frontiers of knowledge are moved is ever more an increasingly valuable experience which engineering educators should endeavour to incorporate in their approaches to teaching.

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