Relating Research and Teaching: Learning From Experiences and Beliefs

Su White
Learning Societies Lab, ECS,
The University of Southampton, UK
+44 (0)23 8059 4471
saw@ecs.soton.ac.uk

Alastair Irons,
Computing, Engineering and Technology
University of Sunderland, UK
+44 (0)191 515 2053
alastair.irons@sunderland.ac.uk

ABSTRACT
The relationship between research and teaching has possible benefits and inherent tensions. Exploring the potentially beneficial relationship is of interest and possible value to faculty, students, and stakeholders. Much of the existing literature has described approaches using a vocabulary derived from the soft/applied social science fields of study, a view-point which may in some ways be problematic. This paper examines the relationship between research and teaching in the undergraduate curriculum from a perspective of the computing disciplines. It compares and contrasts evidence of the beliefs and experiences of faculty about the relationship between research and teaching. It presents and analyses the result of surveys which gathered data to explore their understandings 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’ institutions. Having identified typical activities in the computing disciplines, it places them in the context of existing theoretical models.

Categories and Subject Descriptors
K.3.2 [**Computer and Information Science Education**]: Computer science education – Curriculum

General Terms
Human Factors.

Keywords
disciplinary differences, research-led teaching, research-teaching nexus, scholarship of teaching and learning

1. INTRODUCTION
A primary objective of this paper is to use evidence drawn from current educational practice to situate the debate on the relationship between research and teaching within the computing disciplines. It uses evidence of practice within these disciplines to identify and explore typical understandings, beliefs and experiences of the ways in which research and teaching can be related. It also considers the potential value of developing systematic approaches to linking research and teaching in the computing disciplines.

Alongside conventional educational practice, research practice and the student experience are evermore influenced by rapid technological change. Students’ prior experiences and the expectations of students and stakeholders have changed; and will continue to do so. University educators acknowledge the role of personal learning for life, and the realities of informal learning. These changes to the learning landscape can motivate us to reconsider the potential value of linking research and learning in the computing disciplines. This paper presents some background to the literature which informed the motivation for the research. It then presents an account of the research undertaken, followed by an analysis of the findings with conclusions and suggestions for future work.

2. BACKGROUND
The view that there is a relationship between research and teaching is not a new one. Lewis Elton points out [6] that 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.”

Elton was contributing to the more recent debate, which has influenced institutional strategies and policies today. Current debate considers the possible positive relationship between research and teaching. It owes much to the work of Ernest Boyer, who, on behalf of the Carnegie Foundation looked at the future of undergraduate education [3]. The findings of the Boyer Report reverberated around Higher Education and its associated communities. The follow-up report [4] ensured that the reverberation continued, impacting upon governmental policies, funding directives, institutional strategies and classroom tactics.

The focus of the Boyer Report was intentionally concerned with undergraduate education in research-intensive universities. However readers could 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. Initially the community which debated and researched the relationship between teaching and research included many educational theorists and practitioners whose primary interest and motivation was in educational research and educational development. Unsurprisingly, their findings were largely reported in specialized educational communities. Such communities belong in what Biglan, considering the evidence for disciplinary differences [1] typifies as the world of soft, pure/soft, applied fields of study. It is a world predominantly concerned with social sciences, arts and humanities.

Recently work on the relationship between research and teaching has continued in these specialist communities. There has been some input from faculty heavily engaged in teaching. Some 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. A few participants have emerged from the 'hard-pure/hard-applied' academic communities, but the perspective of the 'soft-pure/soft-applied' disciplines continues to predominate.

Work in the UK has been led by Jenkins and Healey who have produced a substantial body of materials, for example, [7-10]. Their contribution has been through conventional academic publications, plus a set primers and implementation guides aimed at faculty at all levels commissioned by the UK Higher Education Academy. The discipline specific materials have predominantly articulated the social science perspective. Healey has developed a framework to guide the development of the relationship between research and teaching in the curriculum (discussed further below). This is quite different to the four scholarships of research and their application to teaching originally proposed by Boyer (figure 1).

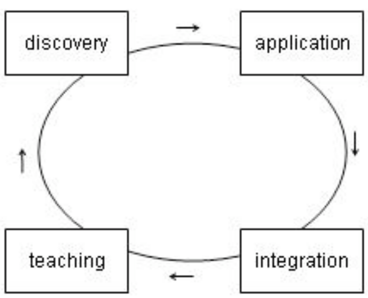

Figure 1 Representing Boyer's Four Scholarships

Boyer's focus on scholarship makes it clear that his work is very much concerned with enhancing 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" [5].

For academics working at the bleeding edge of research, the proposition of the cycle of scholarship offers a means by which they can understand how their research can be related to their teaching. This may be more valued in the quantitative world of hard science and engineering disciplines than in the more qualitative world of social sciences, arts and humanities.

Boyer's work was not without its critics. Drives for research excellence and associated aspirations of exclusivity have had an impact across higher education which seems to have spilled over into the discussion of the relationship between research and teaching. It has been argued that many universities are not research intensive and many university teachers are not active researchers. There has been some feeling that that Boyer's 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, therefore my teaching is research-led*'.

Working from the curriculum, Healey effectively sidesteps the issue of whether the teaching academics are actually active researchers. Instead, Healey draws a distinction between students being *participants* in research activities, or being an *audience* to research activities. He differentiates between research content and research process and offers a conceptualization based on this stance which can be used as an aid to curriculum design. A diagram representing Healey's four approaches is shown as Figure 2 further below.

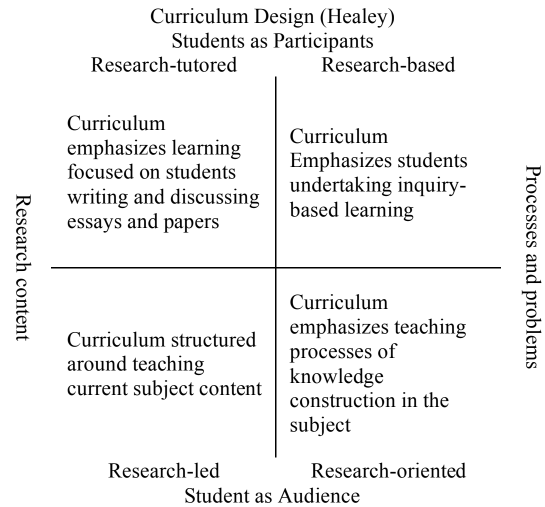

Figure 2 Curriculum Design - Relating Teaching And Research (Adapted From Healey [8])

It has been the experience of the authors that when working with academics from the computing disciplines that examples drawn from our own fields of study 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 [11], however their sample is small, and interviews are with early career researchers rather than with established academics.

The focus of our study is teaching of the computer disciplines. The authors had encountered some difficulty in communicating the conceptual model proposed by Healey to academics in their institutions, yet it was clear after discussions 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. Our academic colleagues' tacit understanding of the relationship between research and teaching appeared to reflect a view which is expressed more formally by Neumann et al [12] whose relatively recent work revisits Biglan's hard/soft, and pure/applied distinctions in fields of study and considers disciplinary differences in teaching. They state: "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 in computing fields of study actively relate teaching and research and thereby identify effective models of usage which motivated the work which is presented below.

3. APPROACH

Following a preliminary survey [13], academics from across the computing discipline 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. 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.

As in the original survey, views were elicited from two universities. The first is a member of the Russell Group of research-led universities. All undergraduate students attend in full-time mode at the main campus, many take a four-year undergraduate masters degree. 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 analyzed to determine whether any of the four approaches described by Healey were being utilized. 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 benefits 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 summarized on a year-by-year basis below.

3.1 UK Educational System

It may be worth reminding readers that in the UK higher education system students typically select and specialize in their final degree outcome from Year One. 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. Degrees considered in this study consist of sets of coherent modules which students are required to pass as a whole before they can progress to the next year of study. There will typically be core modules which are compulsory, and optional modules which students select to achieve their preferred level of specialization.

3.2 Findings Year by Year

Year 1: Initially, students are taught in large cohorts across degree specialisms. Students arrive with heterogeneous skills, knowledge and understanding. Large lecture classes are typically used to motivate study and establish a common base level of knowledge and understanding. Some modules introduce students to concepts of professional practice. Students are paired with lab partners for practical activities where acquisition of knowledge and understanding is integrated with psychomotor 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 academics surveyed educational objectives which offered opportunities for research associated teaching included providing students with the opportunity to:

- 'Think like and 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 researcher who provides 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 subsequent years.

Year 2: Modules are used to consolidate basic skills, knowledge understanding. Again they may be addressed through large lecture classes. Objectives include preparing students for independent work. Research based approaches include teaching research methods and writing exercises which incorporate peer reviewing. Some colleagues offer courses of specialized readings, and there is some small group teaching. At this level students are required to mimic the behavior of researchers, there is greater homogeneity as students' studies progress.

Year 3 – final year bachelors: At this level, there is an increase in small group teaching. Students have greater opportunities for independent study, although not all students are equal in this regard. Many academic objectives address Bloom's higher-level cognitive skills [2]. Reported tasks included preparing research style papers and following reading courses. Practical activities incorporate design and build, and project tasks are set where, according to the judgment of the project supervisor, students undertake more of less open ended activities, some of which offer the opportunity to make new discoveries

Year 4 – final year undergraduate masters: At this level there was much more evidence of explicit/intentional research links. Students were asked to produce demonstration pieces. Writing incorporated research activities including peer review, revision and presentation (typically as a poster). In some cases they were encouraged to participate in research activities such as seminars.

Informal Learning: In addition to opportunities within the formal curriculum, students may experience the relationship between teaching and research through informal learning via internships. It is common for research-intensive universities to offer internships and the value of such internships has been recognized by UK funding council EPSRC who have initiated schemes at some UK universities. Opportunities are available to students irrespective of the nature of their institution through companies offering places in research and development. 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 at the end of year 2 and year 3.

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

Students as Participants

Research-tutored	Research-based
e.g.: classic tutorial structure – typically small group supervisions with technical focus 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 organizational or 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

Research content (left axis) / Processes and problems (right axis)

Figure 3- Repopulating Healey's Matrix

4. DISCUSSION

Response to the survey questions varied according to the type of teaching which was taking place. Undergraduates study a range of topics which can require them to develop knowledge, skills and. 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 computing disciplines makes this a rather complicated instance.

The survey demonstrated that activities which inter-relate research and teaching existed in both a research-intensive and teaching-intensive institution. Existing and state of the art discipline based research played a strong role in educational practices outside of 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 exposing the relationship between research and teaching 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 effective and 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 commented that students are sometimes 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 to establish 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 hard subject areas 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. Findings are transposed to Boyer's framework in figure 4.

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

Where students experienced teaching approaches which were drawn from a research perspective they 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 computer science 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 the scholarship of their teaching explicit to their students. This approach can be particularly useful when bringing about change in an established curriculum as a means of alerting students to the meta-objectives of the activities, and gaining their trust and confidence as an adjunct to introducing them to what may be new methods of learning.

5. CONCLUSIONS

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 computing disciplines have been found and are offered (via the diagrams) 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 discussion revealed that they were more easily able to associate activities with the four stages of scholarship which Boyer originally proposed.

What it patently obvious is that academics across the computing disciplines are not typically social scientists, even if they sometimes use methods which were developed in the social sciences. Indeed the differences between the hard/soft and pure/applied perspectives may serve to make the (soft applied) literature which deals with the relationship between teaching and research more difficult to access, or alien to the typical hard pure and hard applied mindset of the computing disciplines. 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 programmes which address academic practice for new faculty.

This study suggests benefits can be won from additional evidence of current practice. There are opportunities to compare practice across different education systems, learners and academics. Meanwhile, on the horizon, students are arriving at university with the skills sets of the information age. They face a future where the half-life of information is ever shorter and they may work in jobs that do not yet exist. Informal education is increasingly important, and all stakeholders value an ability to learn in a self-sustaining manner. Future work which enquired into technology based practice could add a useful additional dimension to his analysis. Similarly it would be useful to extend the number of institutions surveyed, and to conduct analysis which incorporated teaching approaches in different countries. Even so, the findings suggest that adopting curricula which incorporate research skills, and imbue an understanding of how the frontiers of knowledge are moved is an ever more valuable experience which educators might strive to endeavor to incorporate in their approaches to teaching.

6. REFERENCES

1. Biglan, A., *The characteristics of subject matter in different academic areas*. Journal of Applied Psychology, 1973. **57**(3): p. 195–203.
2. Bloom, B.S., *Taxonomy of educational objectives; the classification of educational goals*. 1st ed. 1956, New York: Longmans.
3. Boyer Commission on Educating Undergraduates in the Research University, *Reinventing Undergraduate Education: A Blueprint for America's Research Universities*, in *The Boyer Commission on Educating Undergraduates in the Research University*. 1998, Stony Brook: State University of New York at Stony Brook: New York.
4. Boyer Commission on Educating Undergraduates in the Research University, *Reinventing Undergraduate Education, Three Years After the Boyer Report*, in *The Boyer Commission on Educating Undergraduates in the Research University*. 2002, Stony Brook: State University of New York at Stony Brook: New York.
5. Boyer, E., *Scholarship reconsidered: Priorities of the Professoriate*. 1990, New York: John Wiley.
6. Elton, L., *Research and Teaching: conditions for a positive link*. Teaching in Higher Education, 2001. **6**(1): p. 43-56.
7. Healey, M., *Linking research and teaching to benefit student learning*. Journal of Geography in Higher Education, 2005. **29**(2): p. 183-201.
8. Healey, M., *Linking research and teaching: exploring disciplinary spaces and the role of inquiry-based learning*, in *Reshaping the University: New Relationships between Research, Scholarship and Teaching*, R. Barnett, Editor. 2005, McGraw Hill / Open University Press: London. p. 67-78.
9. Jenkins, A. and M. Healey, *Institutional Strategies to link teaching and research*. 2005, Higher Education Academy: York.
10. Jenkins, A., M. Healey, and R. Zetter, *Linking of staff disciplinary research and student learning*. 2007, Higher Education Academy: York.
11. Lucas, L. and N. Turner, *Early Career Academics and their Perceptions and Experiences of Linking Research and Teaching* in *Colloquium on International Policies and Practices for Academic Enquiry* 2007, Southampton Solent University: Winchester.
12. Neumann, R., S. Parry, and T. Becher, *Teaching and Learning in their Disciplinary Contexts: a conceptual analysis*. Studies In Higher Education, 2002. **27**(4): p. 405-418.
13. White, S. and A. Irons, *The research teaching nexus in the computing disciplines: a comparative survey*, in *Informatics Education Europe II: On The State Of Informatics Education In Europe*. 2007: Thessaloniki, Greece.