Research Informed Teaching: enhancing the teaching-research nexus in science disciplines

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1. Introduction

Teaching and research are the two most important activities taking place in Higher Education (HE). The link between these two activities has been called the "teaching-research nexus", or "research-led", "research-based", "inquiry-based" or "research-informed" teaching (Jenkins et al, 2007). This chapter aims to provide an overview of the current thinking regarding the links between research and teaching quality. The chapter includes two case studies (from Bioscience and Computing) extracted from the UK HE context, which serve as examples of how the teaching research nexus can be enhanced in science disciplines.

Connecting student learning to research can be highly beneficial for both staff and students. Research active staff may find new stimulation and creativity from undergraduate students, while students can benefit from integrating research into their learning (Boyer, 1998). It is a commonly held view that there is a natural positive relationship between staff engagement in research and the quality of student learning. The assumption is that research active staff will be aware of the current developments in their field, which will in turn enhance their students' learning experience. However, several authors have contested this relationship as a belief unsubstantiated by research and scholarly evidence (Hattie and Marsh, 1996; Jenkins et al, 2003; Elton, 2001). Such studies have shown that, although teaching can benefit from being linked to research, establishing successful links is neither simple nor automatic (Griffiths, 2004).

Appropriate curriculum design can develop students' ability to understand and carry out research, and thus provide the desired link between research and teaching (Jenkins et al, 2003, chapter 1). Successful linkages are strongly dependent on academics' ability to encourage and facilitate an inquiry based approach to learning (Elton, 2001). The challenge is not to focus on the differences between teaching and research, but to seek the potential synergy between the two (Boyer, 1990, as quoted by Jenkins et al, 2003). The focus is on the student learning experience, rather than on teacher excellence.

2. Teaching and research: complementary, antagonistic or independent?

The Dearing report, published in the UK in the late 90s, states that HE should play a major role in shaping a democratic, civilised and inclusive society (Dearing, 1997). According to this report, other purposes of HE are to inspire and enable individuals to develop their capabilities to their highest potential throughout life (so they can contribute effectively to society and achieve personal fulfilment), to increase knowledge and understanding (for their own sake and for the benefit of the economy and society), and to serve the needs of an adaptable, sustainable, knowledge-based economy (Dearing, 1997). Universities need to help students, as well as society in general, deal with the complexity of this knowledge-based economy. Students' understanding of how research contributes to the generation of knowledge and, to an extent, their own ability to conduct research, is vital to enhance their ability to deal effectively with this complexity (Barnett, 2000).

It is a commonly held belief among the academic community that teaching and research have a mutually reinforcing, symbiotic relationship (Griffiths, 2004; Hattie and Marsh, 1996). Under this assumption, teaching effectiveness and research productivity are seen as complementary, almost inseparable; for many, it is this inextricable link that distinguishes universities from other research and educational institutions (Newman 1992, quoted by Hattie and Marsh, 2002). This premise underpins the foundation of research universities (Hattie and Marsh, 2002). However, several authors have contested the existence of this symbiotic relationship as a belief unsubstantiated by research and scholarly evidence. One of the most influential and controversial studies which challenges this view is the one carried out by Hattie and Marsh in 1996 (Hattie and Marsh, 1996). The researchers conducted a meta-analysis of the relation between teaching and research in universities. Their study, based on 58 articles which contributed 498 correlations, covered only the potential links between teaching and research at the individual academic and at the Department level. Due to the lack of sufficient literature, it was not possible to study the teaching-research nexus at institutional level. In their study, Hattie and Marsh analysed various measures of research output (e.g. quality, productivity, citations), and teaching quality (student evaluation, peer ratings). The study also covered different types of university (liberal, research). Irrespective of how the data was analysed, the result was always the same: there was zero correlation between teaching and research. In their 2002 paper, which inspired the title of this section, the Hattie and Marsh concluded that "the common belief that research and teaching are inextricably entwined is an enduring myth. At best, research and teaching are very loosely coupled" (Hattie and Marsh, 2002). The researchers proposed that this "enduring myth" has been created, at least in part "because universities use research as an advertising lure, because academics use research output as market commodities, and because most academics would like it to be true" (Hattie and Marsh, 1996).

Furthermore, many staff involved in both research and teaching activities find the two are in competition or even in conflict, i.e. the time spent on research is time taken away from teaching, and vice versa (Colbeck, 1998). Students can be affected by the negative aspects of research (e.g. lack of availability of staff heavily involved in research), and may develop the perception that they are not stakeholders of research, but mere recipients of it (Jenkins and Healey, 2007). In 1998, the Boyer commission published a report which aimed to be the blueprint for American research universities. In harsh and unequivocal terms, the Boyer report condemned US research universities, arguing that they often "failed, and continue to

fail, their undergraduate populations" (Boyer 1998). The report highlights that, despite obtaining a substantial income from undergraduate tuition fees, research often occurs at the expense of a more integrative scholarship and a concern for undergraduate teaching. Most undergraduates are attracted to prestigious research universities with the promises of excellent research facilities and the possibility of being taught by world-famous professors, leaders in their research fields. However, in most cases undergraduate are taught by teaching assistants and other staff not directly involved in research, and the state-of-the-art research facilities are rarely accessible to them (Boyer, 1998).

Three years after the publication of the Boyer report, the commission published a follow-up which painted a much more positive picture (Boyer 2002). The commission found that undergraduate education had become a priority topic in the agenda of US research universities, and that the issue of undergraduate research had "become embedded in the practice and the rhetoric of undergraduate education". The report highlighted that "supportive leadership, administrative structures, and financial means are all necessary for substantial change". The commission noted, however, that most efforts had been directed at the top students, and that the next challenge was to reach a broader student body.

3. Linking teaching and research

Some of the research discussed in the previous section profoundly undermines any simplistic view that the teaching-research nexus is automatic or always beneficial. In fact, the zero correlation between research and teaching found by Hattie and Marsh has often been used to justify the separation of teaching and research for funding purposes (Hattie and Marsh, 2004). However, the researchers have always contested this as "the greatest misinterpretation" of their work. According to them "This conclusion could meaningfully be made if the correlation was negative, but it is not. Zero means that there can be as many excellent teachers and researchers as there are excellent teachers, excellent researchers, and not-so-excellent teachers or researchers. Zero does not mean that there are no excellent teachers and researchers. It could be claimed that Universities have survived with a zero relationship, but that does not mean that all academics within those institutions are either researchers or teachers." (Hattie and Marsh, 2004).

None of the studies have shown that teaching cannot or should not benefit from being linked to research (Griffiths, 2004). As Hattie and Marsh (2004) say: "The fundamental issue is what we wish the relation to be, and then we need to devise policies to enact this wish". In their 1996 paper they concluded that "universities need to set as a mission goal the improvement of the nexus between research and teaching. [...] The aim is to increase the circumstances in which teaching and research have occasion to meet, and to provide rewards not only for better teaching or for better research but for demonstrations of the integration of teaching and research" (Hattie & Marsh, 1996). If this aim is to be achieved, there is a need to replace the simplistic belief that assumes a straightforward link between teaching and research with more elaborate approaches (Jenkins et al, 2003). Academic staff and university managers must acknowledge the complexity of the various linkages that can be established between both activities, and that university policies will have a profound effect on the types of links established (Jenkins et al, 2003).

In addition, it is necessary to take into account that the relationships between teaching and research will vary according to the discipline or field of inquiry (Jenkins et al, 2003). Even

the definition of what constitutes research varies according to the discipline. Griffiths (2004) identifies the differences in terms of:
-whether knowledge advance is viewed as the production of universal or generalisable theories, or the solution of specific practical problems;
-whether the emphasis is on empirical or theoretical investigation; and
-whether the knowledge is generated in the context of a single established discipline or in a multidisciplinary or interdisciplinary context.
(Griffiths, 2004)

Griffiths also defines four models to explain the teaching-research nexus. These models are:
-Research-led: teaching is based on the traditional 'information transmission' model, and the curriculum is strongly linked to the research interests of academic staff. The emphasis is on understanding the research findings rather than the processes involved in generating these findings. This model does not really capture the two-way benefits of the research–teaching relationship.
-Research-oriented: the emphasis here is on understanding the processes by which knowledge is generated. Attention is focused on teaching inquiry skills to students, as well as a 'research ethos'. Academics' research interests appear in a more diffuse way.
-Research-based: the curriculum is designed around inquiry-based activities. The experiences of staff are highly integrated into the student learning activities. There is a deliberate attempt to exploit the two-way interactions between research and teaching, and the division of roles between teacher and student becomes diffused.
-Research-informed: this model focuses on the inquiry into the processes of teaching and learning themselves.
(Griffiths 2004)

Although it is possible to find these types of interactions between teaching and research in any discipline, Griffiths (2004) argues that their applicability is likely to vary according to the discipline context. This view is shared by Colbeck (1998), who found that, in general, academic staff in an English department seemed to have more opportunities than their counterparts in the Physics department to integrate research and teaching. Colbeck attributes this to the differences in knowledge generation between the disciplines. Knowledge expands horizontally in soft disciplines such as English, where there is little consensus on what constitutes "appropriate" course content. According to Colbeck, hard disciplines such as Physics tend to have a high level of agreement about what constitutes "accepted knowledge" in their field. However, when the focus is on undergraduate research training, academics in hard disciplines find it easier to link teaching to their research interests because the nature of research in these areas tends to be more collaborative. Interestingly, the researcher also highlights that university and departmental policies can serve to moderate these disciplinary influences.

4. Strategies for linking teaching and research

Connecting student learning to research can be highly beneficial for both staff and students. Research active staff may find new stimulation and creativity from undergraduate students, while students can benefit from integrating research into their learning experiences (Boyer,

1998; Hattie and Marsh, 1996). Students value learning in a research-based environment, perceiving their courses as current and stimulating (Jenkins and Healey, 2007).
Appropriate curriculum design can develop students' understanding of research, as well as their ability to carry out research (Jenkins et al, 2003, chapter 1). Successful linkages between teaching and research are strongly dependent on academics' ability to encourage and facilitate an inquiry based approach to learning (Elton, 2001). The focus is on the student learning experience, rather than on teacher excellence. Institutions can also play a key role in strengthening the teaching-research nexus. For example, they can make integrated research and learning a part of their mission statement, and formulate appropriate strategies and policies to manage the conflicts between teaching and research roles (Jenkins et al, 2003, chapter 5).
The following two case studies, both from Canterbury Christ Church University, UK, illustrate how research and teaching have been integrated in two very different science disciplines, Biosciences and Computing. The conceptual challenge is not to focus on the differences between teaching and research, but to seek the potential synergies between the two activities (Boyer, 1990, as quoted by Jenkins et al, 2003).

4.1 Case study I: Another way of assessing undergraduate research projects (Emilia Bertolo, Department of Geographical and Life Sciences)

In order to complete their degree, science students in their final year must carry out a substantial piece of independent research. The project, called Individual Study, is equivalent to 15 ECTS (European Credit Transfer System) credits. The timing for the Individual Study is quite demanding for students, since they must complete it while attending their other (taught) modules. In the past, Individual Studies were assessed in a fairly traditional way: students had to produce a final dissertation (approximately 8000 words), and there was also a viva. A small percentage of marks were awarded by the supervisor, assessing the quality of the research relationship established and the student's motivation throughout the project.
Some concerns regarding the adequacy of the system had been raised by members of the science team over the years. First of all, there were questions as to what extent a one-off piece of work could truly reflect the effort put in during the whole project. Also, since all the deadlines were at the end of the academic year, the system did not provide sufficient encouragement to students to start their project at the earliest opportunity. The academic staff felt that a more balanced assessment strategy, which would truly reflect the work done by the students, would be fairer.
Following examples of good assessment practices at other universities, the science team decided to change radically the assessment strategy for the Individual Study. The assessment for the module now consists of:
– a logbook, 30%;
– a research paper, 30%;
– an annotated bibliography, 10%;
– a viva, 20%;
– the supervisor's assessment of motivation and engagement, 10%.
Students must hand in their logbook approximately three months into the academic year, in order to receive feedback on the research conducted to that point. There is a specific page in the logbook for supervisor feedback, and it includes a section for students to write their reflections on how the project is going and the feedback received. Feedback is given, but

there are no formal marks for handing in the logbook at this stage. However, if it is not handed in, the final mark for the logbook cannot exceed half of the maximum 30%.

Logbooks are provided by the department and have a standard format. Pages are numbered, and students are instructed not remove any of them. The logbook should include all the work undertaken in relation to the project (with dates), as well as Health and Safety information, project summary and proposed timetable, experimental design, materials and equipment, etc. Each section must be agreed (including signature and date) with the corresponding member of the science staff (e.g. Health and Safety Officer, supervisor and technical staff), before research can commence. There is also a section where all student/supervisor meetings are briefly summarised, including objectives to be achieved before the next meeting. This section is signed and dated by the supervisor after each meeting.

Students must write the research paper following the instructions for authors of a peer-reviewed scientific journal of their choice, with the markers acting as hypothetical referees for that journal. Students are assessed on the quality of the research undertaken, the way it is presented, the suitability of the research to their chosen journal, and their ability to conform to the journal requirements. The annotated bibliography should include all references consulted during the project, not only those included in the paper. A small percentage is allocated to the supervisor's assessment of student's motivation. Since this is the most subjective part of the assessment, and cannot be second marked, the mark for this part has been kept low. However, the fact that all meetings between student and supervisor are recorded in the logbook provides a basis for second markers to evaluate to some extent the suitability of the mark given. During the viva students give a short, time-limited presentation on their research to staff and fellow students in a conference-style setting, and the audience is given the opportunity to ask questions.

We believe this assessment strategy is a better reflection of the research undertaken by the students and their commitment and motivation throughout the project than the previous method. Although it is likely that this system means more work for students (who must hand in several pieces of assessment), it is spread more evenly throughout the academic year and student feedback has always been very positive. Students value the diversified assessment strategy, which allows them to strengthen the various traits needed to become a good researcher. This strategy also encourages them to keep up to date notes of their research, by means of the semi-structured logbook. Preparing a research article for a real scientific journal allows students to experience one of the final stages of the research process, preparing their work for submission to an appropriate peer-reviewed journal. When the project is of sufficient quality to get published, the process is much simpler, since the work produced is already in the right format for publication. The format of the viva also prepares them for conference-style presentations of their research. Overall, the change in the assessment strategy has proven very positive for both science staff and students. Moreover, external examiners have always been very complimentary, recognising the benefits of this type of assessment in enhancing students' ability to conduct research.

4.2 Case study II: Research-Informed-Teaching project on Cybercrime Forensics: using Research-Informed-Teaching to enhance the learning of professionals (Denis Edgar-Nevill, Department of Computing)

The Research-Informed-Teaching (RIT) project in Cybercrime Forensics ran from January 2007 to July 2008. It involved students on the Cybercrime Forensics MSc, jointly validated and taught between the Department of Computing, Canterbury Christ Church University and the National Policing Improvement Agency (NPIA), which is responsible for all high tech specialist training for the regional police forces in the UK. In the second year of the project, students studying on the BSc Forensic Computing degree were also involved.

Engaging professional people working at the cutting-edge of their disciplines is not always easy. They can have very strong convictions that what they are doing is 'the right way' for things to be done, and may also distrust the ideas of people outside their normal circle of work. Students on the MSc course here exhibit all of the traits one might expect in serving police officers. They are assertive and forthright in their opinions. Members of the force are also a very tight-knit band, treating others as outsiders. While necessary in many contexts, these attributes can be a barrier to the educational process where new ideas from a variety of sources are valued and considered alongside practical experience.

The RIT Cybercrime Forensics project was focused on breaking down all these barriers. Cybercrime forensics is a very new discipline. Changes in legislation, the offences that require investigation, approved procedures and the underlying computer technology take place all the time; the shifting sand is being blown very quickly. To be effective those working in high tech crime units must be able to keep up with new developments. To assist in this process the RIT project created the infrastructure to bring students together with others in the field.

The project helped to establish the annual International Conferences on Cybercrime Forensics Education and Training (CFET). These have brought together police officers, civilian experts working within high tech crime units and in private sector security companies, software developers and academic researchers from around the world. The conferences have involved the MSc students as participants delivering co-authored papers. They have allowed students to consider a wide range of new ideas for developing their own areas of interest as well as show-casing their own work for wider peer review.

The project has funded both master-classes, bringing in external speakers, and the MSc students themselves (as established expert practitioners) to teach undergraduate students. Moreover, the project has funded research trips to local centres of excellence to form wider networks. It has also given staff opportunities to present papers at international gatherings, developing and encouraging them to contribute to and enrich the research materials being discussed.

One important result has been to raise the profile of the Department nationally. We were invited to propose the formation of a new national British Computer Society Cybercrime Forensics Specialist Group in 2008. This group will continue the work begun with the RIT project on a national scale across professionals working in the field.

5. Conclusion

A substantial body of evidence now exists on the nature of the research–teaching nexus in HE. The general conclusion emerging from this research is that we must abandon the

simplistic view that links between teaching and research are automatic or always beneficial. However, that does not mean that teaching and research cannot or should not benefit from being linked to each other. Successful linkages between teaching and research greatly depend on academics' ability to encourage and facilitate an inquiry based approach to learning. Their focus must shift from teacher excellence to the enhancement of the student learning experience.

Connecting student learning to research can be highly beneficial for all the parties involved in the process. For academic staff, forging productive links between teaching and research helps them to balance their roles as teachers and researchers. Balancing the main roles of academic staff improves their efficiency, to the benefit of university managers. Moreover, as the second case study illustrates, developing the teaching-research nexus can help to raise the research profile of departments and encourage staff to engage in research. Finally, for students, integrating research into their learning experience can be stimulating and challenging, and help to develop them towards a future role as a researcher.

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The widespread deployment and use of Information Technologies (IT) has paved the way for change in many fields of our societies. The Internet, mobile computing, social networks and many other advances in human communications have become essential to promote and boost education, technology and industry. On the education side, the new challenges related with the integration of IT technologies into all aspects of learning require revising the traditional educational paradigms that have prevailed for the last centuries. Additionally, the globalization of education and student mobility requirements are favoring a fluid interchange of tools, methodologies and evaluation strategies, which promote innovation at an accelerated pace. Curricular revisions are also taking place to achieved a more specialized education that is able to responds to the society's requirements in terms of professional training. In this process, guaranteeing quality has also become a critical issue. On the industrial and technological side, the focus on ecological developments is essential to achieve a sustainable degree of prosperity, and all efforts to promote greener societies are welcome. In this book we gather knowledge and experiences of different authors on all these topics, hoping to offer the reader a wider view of the revolution taking place within and without our educational centers. In summary, we believe that this book makes an important contribution to the fields of education and technology in these times of great change, offering a mean for experts in the different areas to share valuable experiences and points of view that we hope are enriching to the reader. Enjoy the book!

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