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Can inquiry-based learning strengthen the links between teaching and disciplinary research?

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Inquiry-based learning has been promoted as a student-centred approach that can strengthen the links between teaching and research. This article examines the potential of inquiry-based learning to strengthen the teaching–research nexus by analysing three case studies: a 'structured inquiry' third-year endocrinology medicine module, a 'guided inquiry' second-year political communications course and an 'open inquiry' third-year ecology course. The relation between teaching and research differed significantly amongst these three cases and led to a reconceptualisation of inquiry-based learning. A model was then developed to link the focus of learning (using Levy's framing of information or discovery-oriented inquiry) with the level of independence and the potential strength of the teaching–research nexus. The findings show that, if teachers are aiming for strong links between teaching and research, they should adopt an open, discovery-oriented inquiry-based learning approach. However, more structured and guided forms of inquiry can be useful to progressively develop particular inquiry skills.

Keywords: inquiry; inquiry-based learning; research-teaching nexus; undergraduate research

Introduction

> If there is to be a closer alignment between the needs of staff and the benefits for students, a new pedagogy for the twenty-first century may be required. The rediscovery of a curriculum devised around inquiry-based learning would be a strong contender. (Healey 2005, 197)

This quote, made in the context of geography curricula, highlights two recent thrusts in higher education. The first is a move towards more student-centred learning (Biggs 2003; Ramsden 2003), while the second is a call for stronger links between teaching and disciplinary research (e.g. Badley 2002; Boyer Commission 1999; Brew 2003, 2006; Jenkins, Healey, and Zetter 2007; Healey and Jenkins 2009; Rowland 1996). Inquiry-based learning has been promoted as a student-centred pedagogy which can both enhance student learning outcomes, particularly the development of higher order skills (Justice, Rice, and Warry 2009; Prince and Felder 2006; Spronken-Smith et al. 2008a, b), as well as strengthen the teaching–research nexus (e.g. Healey 2005; Healey and Jenkins 2009; Jenkins et al. 2003). Justice et al. (2007) commented that inquiry-based learning refers to both a process of seeking knowledge and new

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understanding, as well as a method of teaching. Thus, they saw inquiry-based learning as similar to research, and as a way to integrate research and teaching where both students and teachers are 'compatriots in the search for knowledge' (202).

Whilst inquiry has arguably been the mainstay of academic endeavour for centuries, the rise of inquiry-based learning as a pedagogy has been more recent. John Dewey, an American educator, was largely responsible for promoting 'learning by doing' (Dewey 1933), and inquiry-based learning is an example of an experiential learning approach. Inquiry-based learning was adopted by many school teachers in the 1970s and began to appear about the same time in tertiary institutions. However, the use of inquiry-based learning in higher education has been patchy, despite calls for it to be an integral part of curriculum design. For example, Healey (2005) argued for greater use of research-based teaching using inquiry-based learning. He developed a matrix (amended by Healey and Jenkins 2009) showing the link between curriculum design and the research–teaching nexus (Figure 1). He suggested that most conventional university teaching occurs in the bottom left (research-led) quadrant of Figure 1, although he recognised that some disciplines have relatively more activity in the other quadrants. He argued that higher education should place more emphasis on pedagogies that lie in the top half of Figure 1 – i.e. those that are either research-tutored or research-based (including learning through inquiry) – since these models have the most benefit for student learning.

In New Zealand the Tertiary Education Strategy calls for 'a research culture within which undergraduates learn to take a research-based approach to their lifelong educational development' (Ministry of Education 2002, 60). This reflects the legislative requirement that research and teaching in New Zealand universities and all

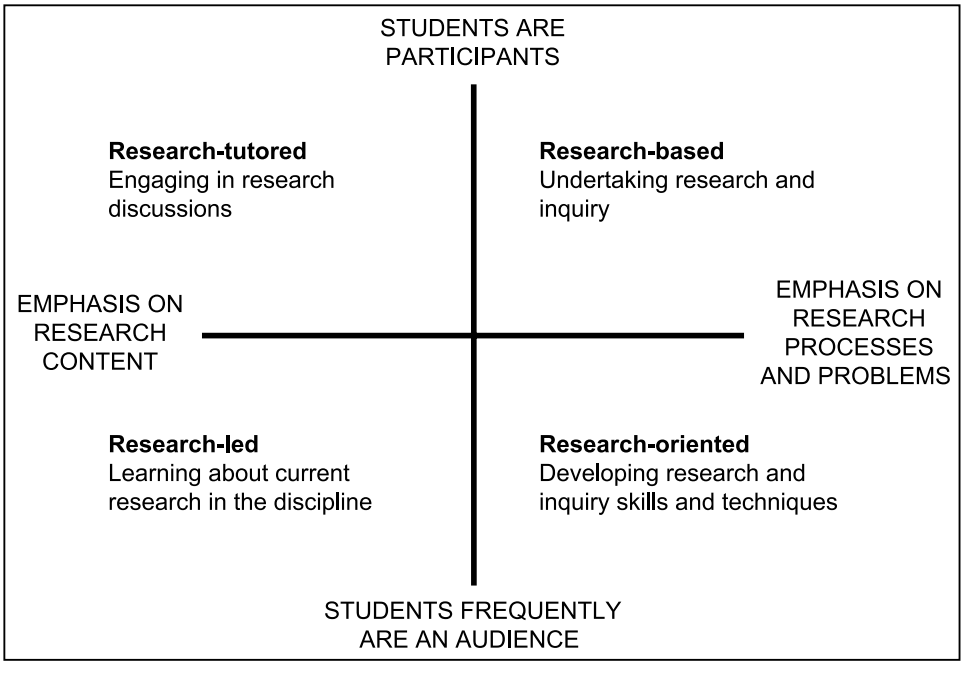

Figure 1. The links between curriculum design and the research–teaching-nexus (Healey and Jenkins 2009, 7).

degree-granting organisations are closely interdependent, and that most teaching in such organisations should be done by people who are active in advancing knowledge (New Zealand Government 1989). Despite this legislation, Robertson and Bond (2005) commented that relatively little attention had been paid locally to the ways in which the relation between teaching and research was enacted. However, the focus of the academic audit of New Zealand universities in the year 2001 was on the links between teaching and research, and this promoted a great deal of thought in institutions as to how the nexus was manifest. The introduction of a Performance Based Research Fund in New Zealand in 2003, with the consequent focus on research productivity (potentially at the expense of teaching quality), also made this a very opportune time to focus on the relation between research and teaching. Several studies have emphasised the complexity of the nexus resulting from factors such as the nature of the institution, the disciplinary context and views of knowledge, scholarship, research, teaching and learning (e.g. Brew 2003, 2006; Robertson 2007; Robertson and Bond 2005). Robertson (2007) argued that the nexus was plural, and postulated variation from a weak relation in a science context through to an integrated relation in a humanities context. Noting disciplinary differences, Brew (2003) argued for a reconceptualisation of the nexus, centred on academic communities of practice (Lave and Wenger 1991), in which teaching and learning should occur in communities of inquiry with academics and students as co-learners. Furthermore, she suggested that such communities of inquiry should be accessible to all undergraduates, not just the high achievers or elite institutions.

Our article challenges the notion that all types of inquiry-based learning can indeed strengthen the links between teaching and research, as we believe that simply talking about 'inquiry' or 'inquiry-based learning' may miss the nuances associated with different types of inquiry-based learning. Our research involves an empirical study of three different types of inquiry-based learning, examining in each the links between teaching through inquiry and disciplinary research. This cross-case analysis generated a conceptual model showing the relation between different types of inquiry-based learning and the potential for a strong teaching–research nexus. We will show that the potential of inquiry-based learning to strengthen the links between research and teaching is only realised in some types. It is, therefore, critical to have a clear understanding of what inquiry-based learning entails, and how it may take different forms. Accordingly, this article addresses two main research questions. First, what is inquiry-based learning, and second, what types of inquiry-based learning can strengthen the links between teaching and disciplinary research? Whilst we address the meaning of inquiry-based learning in the introductory material, through the research process our understanding of it further developed, necessitating a reconceptualisation that is later discussed. The article continues by exploring our understanding of the term inquiry-based learning at the inception of the research. Following this, the research methodology is detailed and results are presented and discussed.

What is inquiry-based learning?

The nature of inquiry-based learning is contested and even the term itself is not in widespread use throughout the educational literature. Many terms are used for learning through inquiry, including 'enquiry-based learning', 'guided-inquiry', 'problem-based learning', 'undergraduate research' and 'research-based teaching'. Despite this

diversity in terminology, there is a commonality of opinion about what constitutes inquiry-based learning. The core ingredients of an inquiry-based learning approach that many researchers (e.g. Justice et al. 2007; Kahn and O'Rourke 2004; Weaver 1989) are in agreement with are:

- learning is stimulated by inquiry, i.e. driven by questions or problems;
- learning is based on a process of constructing knowledge and new understanding;
- it is an 'active' approach to learning, involving learning by doing;
- a student-centred approach to teaching in which the role of the teacher is to act as a facilitator; and
- a move to self-directed learning with students taking increasing responsibility for their learning.

The learning outcomes of inquiry-based learning typically include the development of skills in self-reflection, critical thinking, the ability to undertake independent inquiry, responsibility for own learning and intellectual growth and maturity (Lee et al. 2004).

Despite a lengthy history, the literature base for inquiry-based learning is at best patchy and diffuse, and, although there are several recent volumes that describe the teaching approach and provide readers with a range of examples (e.g. Aulls and Shore 2008; Lee et al. 2004; Shore, Aulls, and Delcourt 2008), most literature appears in pockets amidst educational and disciplinary journals, usually due to enthusiasts attempting to encourage others to try the approach. More recently, due to the rise of Centres for Excellence in Learning and Teaching in the UK – a few of which focus on inquiry – there has been research examining the use of inquiry-based learning across a range of contexts (e.g. Deignan 2009; Levy and Petrulis 2007; Wood and Levy 2009).

Types of inquiry-based learning

Several types of inquiry-based learning are discussed in the literature, and they are primarily based on three important qualifiers about the nature of inquiry: the level of scaffolding, the emphasis of learning (existing knowledge or building new knowledge) and its scale (within-class, within-course, whole-course, whole-degree).

The notion of scaffolding stems from the work of Lev Vygotsky (1978), who introduced the concept of the 'zone of proximal development', which referred to the zone in which learning occurred with the help of a more capable peer. Wood, Bruner, and Ross (1976) used the term 'scaffolding' to refer to the process in which the learner gradually takes over the learning independently. In practical terms, scaffolding means providing more support and guidance at the start, and gradually tapering off support until the student can do the task themselves. When applied to developing inquiry skills, at introductory levels learning may be heavily scaffolded, with teachers providing an issue or question, as well as an outline for addressing it, whilst at more advanced levels learning may be lightly scaffolded, as students generate the questions themselves and determine how to address them. Thus, as the level of scaffolding decreases, the independence of the students should increase. Staver and Bay (1987) distinguished between structured, guided and open modes of inquiry, and their

classification provides a useful link to scaffolding. Their definitions were particularly oriented towards problem solving, but we broadened their categories to allow exploration of issues:

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- structured inquiry – where teachers provide an issue or problem and an outline for addressing it;
- guided inquiry – where teachers provide questions to stimulate inquiry but students are self-directed in terms of exploring these questions;
- open inquiry – where students formulate the questions themselves as well as going through the full inquiry cycle.

An issue central to the nature of inquiry-based learning is whether the focus of learning is on existing disciplinary knowledge or whether it involves constructing new disciplinary knowledge. We regarded inquiry-based learning as an umbrella term, with problem-based learning as a subset. The focus of problem-based learning, particularly in medical contexts, tends to be on students learning an existing body of knowledge, whereas other types of inquiry-based learning may be more concerned with constructing new knowledge. It was only later in the research project that we discovered the concurrent work of Philippa Levy and her team at Sheffield University, who explored different framing of inquiry-based learning (information-oriented or discovery-oriented). Levy's research is considered later in the discussion.

Finally, inquiry-based learning can occur at a range of scales within the curriculum, from being a discrete activity through to providing the design principle for the whole degree (Spronken-Smith et al. submitted). Spronken-Smith et al. (2008a) reported a series of cases of inquiry-based learning in geography, from within-class activities through to inquiry courses and then inquiry degree programmes. They argued that while smaller scale inquiry-based learning activities are useful, particularly to progressively develop research skills, the most benefit in terms of learning outcomes occurred with inquiry courses or degree programmes.

Research methods

Our analysis stems from a multi-institutional research project in which we examined the use of inquiry-based learning in undergraduate teaching in New Zealand (Spronken-Smith et al. 2008b). Our analysis suggested differences in the nature of the teaching–research nexus across the different modes of inquiry-based learning. Consequently we purposively selected three cases representing the different modes of inquiry-based learning (structured, guided and open) for detailed analysis. These cases were all from the University of Otago: a stage 3 endocrinology module (structured inquiry); a stage 2 political communications course (guided inquiry); and a stage 3 ecology field course (open inquiry), with further details provided in Table 1.

The research was conducted within an interpretivist paradigm and used a case-study approach, with mixed methods of data collection. The teachers/course designers were interviewed to determine their understanding of inquiry-based learning, why and how they used inquiry, their evaluation of the course, and the links between their use of inquiry and their research and teaching. The inquiry courses/activities were also observed by one of the authors, with field notes taken and, in some cases, activities were digitally recorded (photographed and videoed). Some quantitative data were also

Table 1. Characteristics of the three cases of inquiry-based learning used for the cross-case study.

Case	Number of students*	Number of teachers*	Mode of inquiry	Nature of course/module
Stage 3 Endocrinology Medicine Module	230 (focus group of 6)	10 (3)	Structured	16 groups of about 14 students met weekly with their tutor and worked in small groups on cases
Stage 2 Political Communications Course	31 (28)	1 (1)	Guided	2 student groups of about 15 met weekly with their teacher to cover a series of topics that were framed through questions
Stage 3 Ecology Field Course	35 (29)	4 lecturers and 3 teaching assistants (2)	Open	Students undertook a field research project under the guidance of teachers

*Sample size for qualitative data in brackets.

collected as teachers were asked to complete a checklist (Table 2) of inquiry features for their course.

Several forms of data were collected from students. Two survey instruments were used: an inquiry-based learning survey and a course evaluation (see details at: http://akoaotearoa.ac.nz/project/inquiry-based-learning/resources/books/appendix-c-inquiry-based-learning-report). The inquiry-based learning survey explored the type of learning encouraged in the course, student experiences of inquiry-related features, and requested feedback about features in the course that were particularly valuable. The course evaluation comprised 10 standard questions, including one that asked whether the course developed students' ability to engage in research-related activities. Near to completion of the course qualitative data were gathered regarding students' understandings of inquiry-based learning and their experiences of the inquiry approach. Probes were included about students' understandings of the relations between their teacher's research and teaching and their learning, and the extent of their awareness of participating in a community of inquirers/researchers. These data were obtained from feedback sessions run with the whole class (for both the political communication and ecology courses) or from a focus group (endocrinology).

A cross-case analysis was conducted to determine whether the different modes of inquiry-based learning strengthened links between teaching and research. Finding indicators of a strong teaching–research nexus proved problematic, especially given the different disciplinary contexts and the influence this may have on the nexus. We drew on the work of the Boyer Commission (1999) and Brew (2003) to provide some indicators. These were: the emphasis of learning (whether it was on existing knowledge or generating new knowledge); whether the students' inquiries were aligned with teachers' research interests; whether teachers were co-learners; whether there was any teaching of research process and development of research skills, whether students felt part of a community of practice of researchers; and student and teacher perceptions of the links between research, teaching and learning. Data relating to these indicators

Table 2. Inquiry-based learning checklist completed by teachers. Each question was rated using the following scale: always, usually, sometimes, rarely, never.

Focus of inquiry
Are there open-ended questions that lead to the formation of defensible answers?
Are tasks focused on areas that have more than one possible outcome?
Do students work through the process of constructing knowledge?
Do the questions challenge students?
Are there elements of student choice in selection of questions, context of application and/or methods of inquiry?
Does the inquiry align with the teacher's research interests?
Role of teachers
Are teachers there as co-learners?
Do teachers act as facilitators?
Inquiry approaches and processes
Is there teaching of the research process?
Are relevant transferable skills taught?
Are the outcomes, teaching method and assessment well aligned?
Is there a transparent assessment scheme?
Do students collaborate in their learning?
Do students reflect on the process of constructing knowledge?
Is there a move to self-directed learning and increased responsibility?

were gained from both qualitative and quantitative data sources, as described above. Thomas's (2006) general inductive approach was used for analysis. In this approach key themes are drawn out in relation to the research objectives, as well as allowing themes to emerge from the raw data.

Based on the summation and triangulation of evidence across the qualitative and quantitative data we inferred the likely strength of the nexus. Through the research process, and in light of research by an inquiry group at Sheffield University, it became apparent that our conception of inquiry-based learning needed revisiting, so the final step in analysis was to reconceptualise inquiry-based learning based on our new understanding.

We now briefly describe each of the cases, together with an analysis of the teaching–research nexus. This is followed by a synthesis across the three cases, including further consideration of the defining features of inquiry-based learning.

Endocrinology module – structured inquiry-based learning

In this structured inquiry endocrinology module, students prepared for weekly sessions by undertaking background reading and learning factual material. In the group session, students were introduced to a series of cases that they had to solve in teams of about seven. Students were given a combination of formative (online tests) and summative assessment (a final examination that involved an endocrine case).

Analysis from the inquiry-based learning survey (Figure 2) and checklist (Table 3) showed that students and teachers respectively thought the module encouraged skills and learning typical of inquiry courses. For example, students rated the module highly

for encouraging learning for understanding, analysing and applying (Figure 2a), as well as taking responsibility for their own learning, solving problems and being challenged (Figure 2b). However, 71% thought the course encouraged *a great deal* or *quite a bit* (these were the two most positive choices on the 5-point Likert scale; Likert ratings are presented here in italics) of memorisation, a feature not commonly associated with inquiry-based learning approaches. Furthermore, there was little opportunity for creativity and reflection, and nor was there much choice in terms of what they could study.

This module was focused on existing disciplinary knowledge; although teachers said the questions were *usually* open-ended, they added the caveat that they were seeking the one 'right' answer. Furthermore, it was apparent that inquiry-based learning was not really strengthening the teaching–research nexus. The course evaluation data showed that only 9% of respondents *strongly agreed*, and 25% *agreed*, with the statement that the course helped develop their ability to engage in research-related activities – by far the lowest rating for any of the evaluative questions. Also, as Table 3 shows, only *rarely* was the inquiry aligned with teachers' research interests in medicine. The only alignment was for one of the tutors who had research interests in medical education. Thus, with the exception of this tutor, teachers were never there as co-learners. There was *rarely* any teaching of research process.

The interview and focus group data provided an opportunity to further probe aspects of the teaching–research nexus. The three members of the course design team all commented that there was no disciplinary link between their teaching in this module and their pathology research. One elaborated:

> This is service teaching, and we actually don't even aim to teach them advanced kind of current stuff because that's not particularly relevant, and it would be very distracting, in fact, from what we think they need to know.

This quote provides some insight into the teacher's philosophy and consequent focus of the module, which is more concerned with covering certain content areas that the teachers perceived students needed to know. Similarly, some facets of the link were not there for the students. They commented, 'not sure what his research is' and 'doesn't really apply'. There was a sense of community in the tutorial groups, but not a sense of a community of inquirers or researchers.

Although many inquiry-based learning courses explicitly engage students in research to develop research skills, this module did not set out with this aim. Rather, the aims were more content and clinically oriented, in a typical problem-based learning fashion. Thus, in this case, we concluded that there was little evidence of a link between teaching and research for either students or teachers. Nevertheless, this structured inquiry approach certainly met the teacher's aims and provided students with a rich and engaging learning environment.

Political communications in New Zealand – guided inquiry-based learning

This guided inquiry course involved students covering a series of prescribed topics, but these were framed through a series of questions that were addressed in weekly group meetings. Preparation for group meetings included accessing online resources and undertaking reading, as well as listening and watching media clips. Based on this

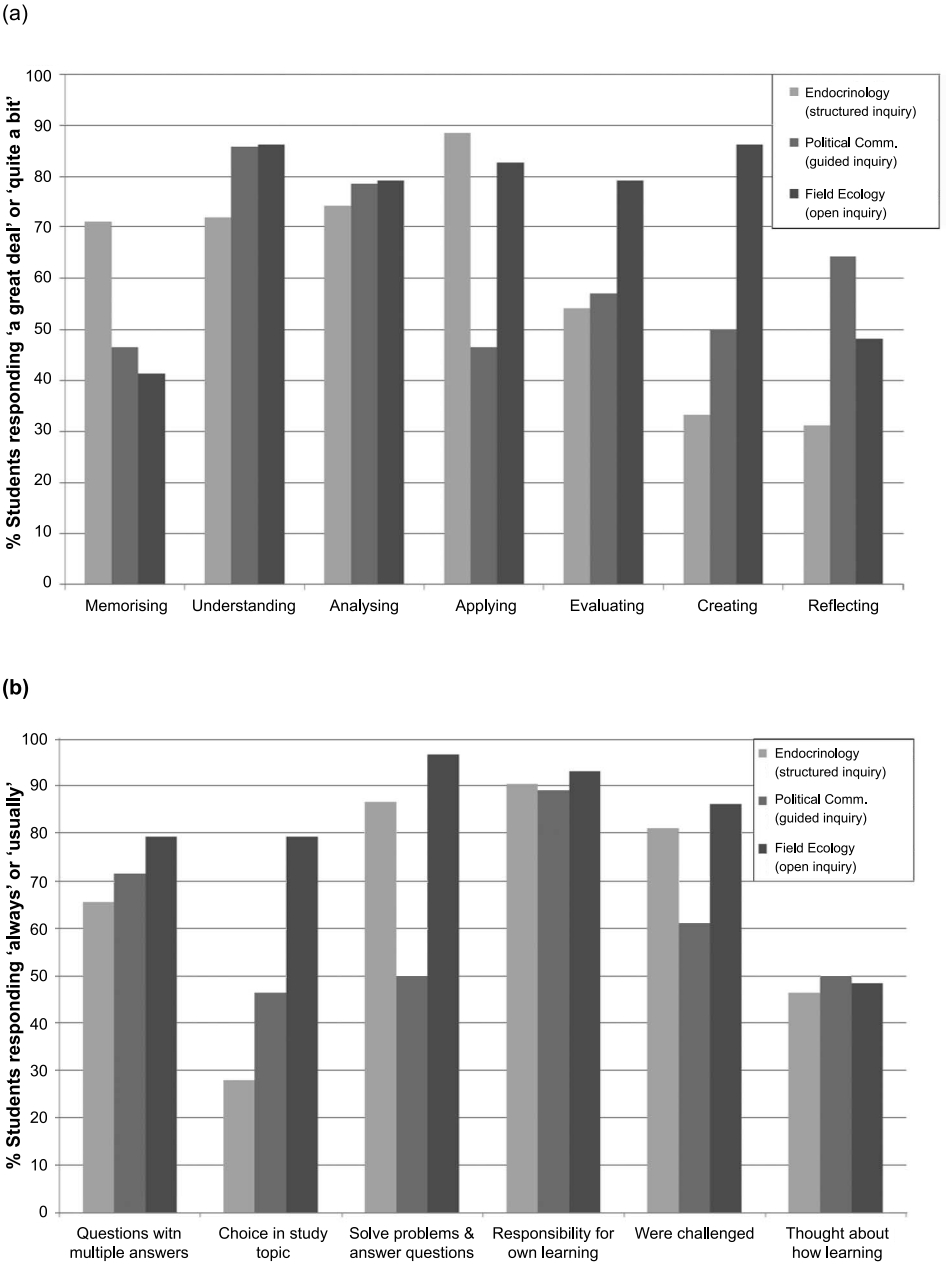

Figure 2. Student perceptions of (a) the type of learning encouraged in the course, and (b) learning processes in the course. Data are from the inquiry-based learning survey (n = 220 for Endocrinology; 28 for Political Communication and 29 for Ecology Field Course). Student responses for the two most positive categories on the Likert scale were summed and are reported as a percentage of the sample.

Table 3. Comparison of course design aspects for the Endocrinology structured inquiry module, the guided inquiry Political Communications course and the open inquiry Ecology Field course.

Feature	Endocrinology – structured inquiry	Political Communications – guided inquiry	Ecology Field Course – open inquiry
Aspects of the learning process			
Open-ended questions?	Usually	Usually	Always
Challenging questions?	Usually	Usually	Usually
Elements of student choice in study?	Rarely	Sometimes	Usually
Student collaboration in learning?	Always	Sometimes	Always
Student reflection on process of constructing knowledge?	Sometimes	Rarely	Sometimes
Move to self-directed learning?	Always	Always	Always
Teachers as facilitators?	Always	Always	Always
Teaching of relevant transferrable skills?	Always	Usually	Usually
Aspects of the teaching–research nexus			
Emphasis of learning?	Existing body of knowledge	Process of generating new knowledge	Process of generating new knowledge
Breadth of study?	Narrow and focused	Wide but prescribed	Wide and varies according to student interest
Inquiry aligned with teacher's research interests?	Rarely	Usually	Usually
Teachers as co-learners?	Never*	Usually	Usually
Teaching of research process?	Rarely	Sometimes	Always
Students part of a community of practice of researchers?	Never	Partly	Mostly

*Except for one tutor with medical education interests.

preparatory material, group discussions focused on key questions and the teacher used a series of brainstorming and task-oriented methods to get students to cover broad content areas. Students were assessed via a series of learning logs, an in-class test and an essay.

As Table 3 and Figure 2 shows, students addressed challenging, open-ended inquiry questions, *sometimes* worked through the process of constructing knowledge, and *sometimes* collaborated in their learning – particularly during the group sessions. In terms of the type of learning encouraged, students rated most highly understanding and analysing (Figure 2a). Less highly rated were applying, creating and solving problems and answering questions. There was also perceived to be less choice about studying, although students could choose their major essay topic.

The teaching–research nexus was key to the course, particularly for the teacher. For example, he commented:

> It's very interesting because I can actually set them tasks or problems which are mini versions of what I am, myself, doing … That's when I think students will only ever learn techniques of research by actually doing it … and I want to involve them and get them to participate because I think that's the only way they'll understand … I think involving them in, not just going out and doing the readings, but actually doing some mini research programmes, teaches them a whole host of things about working with other people, overcoming problems, dealing with things that don't work out how they should.

This teacher had a strong belief in students learning through doing. Thus, his course design was based around a series of typical disciplinary research tasks, involving the students in the research process. He believed it was important to let the students experience the practicalities and difficulties of research as this would lead to better understanding.

Despite the high value he placed on close ties between research and teaching, and his strong belief in developing research skills in his students, he was not explicit about his research to students. For example, he commented:

> To read what I've done and published because I can see they'll be saying, 'ohh, well [he] said this and [he] said that' and I don't want them to sort of think, 'well this is how he did it. This is what they've said they did'. I want them to do it, find out themselves rather than just trying to follow a format that I've come up with.

In this disciplinary context, the teacher thought it was vital for students to think for themselves and make their own judgements. Thus, he was reluctant to discuss his own reasoning, rather placing the onus on students to discuss and debate, and to form their own opinions.

Given this teacher's philosophy about wanting students to develop independent thought, and his reticence to openly discuss his own research, it was perhaps not surprising that his students struggled to answer questions about teaching–research links in this course. There was little awareness of the link, although they valued the research skills they had acquired but did not often explicitly recognise these as such. In the course evaluation 33% of the respondents *strongly agreed* with the statement that this course helped them engage in research-related activities, while another 33% *agreed*. In the feedback session students commented they used the teacher's textbook and this was seen to link to his research.

For this case we surmised there was a moderate strength of the teaching–research nexus. Although the links between teaching and disciplinary research were seen to be

strong for the teacher, the students had less awareness of the links. They did not see themselves as apprentice researchers and had little sense of being part of a community of inquirers.

Ecology field course – open inquiry-based learning

This stage 3 ecology open inquiry course began in the field with a week-long residential field trip, where students learned to question ecological patterns and processes in the landscape, and subsequently worked with one or two peers to generate a research question to be tackled. Field data were gathered on the trip and analyses were completed once back on campus. Students were assessed on their participation in fieldwork, and on oral and written presentations of their research.

Figure 2 and Table 3 show that this course was encouraging skills and learning typical of inquiry-based learning courses. As Table 3 shows, students *always* addressed open-ended questions that were *usually* challenging, and they *always* constructed knowledge that was *usually* new to the teachers. Students perceived the emphasis of the course to be on creativity, understanding, analysing, applying and evaluating (Figure 2b), all higher order metacognitive skills. Figure 2b shows that, compared to the other inquiry-based learning cases, this course was most highly rated for having multiple answers, student choice in what was studied, the emphasis on solving problems and answering questions, students taking responsibility for their own learning and being challenged.

In terms of the teaching–research nexus, topics of inquiry were *usually* aligned with teachers' interests, teachers were *usually* co-learners, and there was *always* teaching of research process (Table 3). In the interview one of the teachers commented, 'For me personally, it's a two-way process', both through guiding students in the research process and for teaching informing her research. She commented further that 'it's [student research] challenging me to actually challenge my own perspectives'. Students also picked up on a strong teaching–research nexus. In the course evaluation, 72% of the respondents *strongly agreed* with the statement that the course helped develop their ability to engage in research-related activities, and another 22% *agreed* with this. Feedback from students in the inquiry-based learning survey and the class feedback session found that the most valuable part of the course was learning about the research process. They knew about their teachers' research interests (one commented that they had 'gained insight from casual conversations'), they knew they were being explicitly taught research skills, many felt part of a community of researchers/inquirers and some talked about the notion of this course being like an 'apprenticeship in research'.

In this case we concluded there was a very strong teaching–research nexus for both students and teachers. Students pursued topics of interest to teachers and often teachers were co-learners in the process. Nearly all students thought the course was helping to develop their research abilities and several commented that they were apprentice researchers. There was a strong sense of being in a community of inquirers.

Synthesis across the cases

Although the process of learning was in many respects similar across the different modes of inquiry-based learning, facets of the teaching–research nexus were very

different (Table 3). In terms of the learning process, the features of commonality were that a problem or question was a trigger for learning, students collaborated in learning, there was a student-centred approach with teacher as facilitator, and a move towards self-directed learning. Furthermore, there was teaching of relevant transferrable skills. However, there was a range of student choice in terms of topics studied, from *rarely* in the structured inquiry endocrinology module to *usually* in the open inquiry ecology field course. All courses rated poorly on student reflection on the process of constructing knowledge (Table 3), as well as encouraging students to think about how they were learning (Figure 2b). This issue was raised with the teachers, who subsequently are working to build in more reflective activities into the courses.

Regarding the teaching–research nexus, there were notable differences between the modes of inquiry-based learning for all the key indicators. Whereas the guided, and especially the open, inquiry courses had typically stronger teaching–research links, this was not apparent in the structured inquiry case. The structured inquiry endocrinology module was mainly focused on students learning a set body of content. In contrast, the guided inquiry political communication course, and especially the open inquiry ecology field course, were more concerned with students learning about the process of constructing knowledge in the discipline. The ecology field course had a very strong teaching–research nexus – for both teachers and students. For such open modes of inquiry-based learning there is likely to be more student choice regarding the topic of study, an increased capacity to do research, and an increased capacity for a community of practice as students identify with a community of inquirers/researchers. That the ecology course had evidence for a strong nexus challenges the view put forward by Robertson (2007) that the nexus may be weaker in a science context.

Reconceptualising inquiry-based learning

Concurrent to our research, Philippa Levy and her team at the Centre for Inquiry-Based Learning in the Arts and Social Sciences (CILASS) at the University of Sheffield were developing a theoretical framework to explain students' experiences of inquiry in the curriculum (Levy 2008, 2009; Levy and Petrulis 2007). In a similar way to Healey (2005), they developed a matrix to show the relation between who framed the inquiry and the inquiry process (staff- or student-led), and whether students viewed the inquiry experience through an 'information frame', in which they explored and acquired existing disciplinary knowledge, or through a 'discovery frame', in which they participated in building on and contesting disciplinary knowledge (Figure 3). Their resulting classification has some similarities to the classification we adopted (structured, guided, open), but importantly it is rooted in student experiences.

Levy's (2009) matrix makes a very useful contribution to developing the theoretical base for inquiry-based learning. Although Levy makes the significant distinction between information and discovery frames, we think it is also important to further distinguish between the amount of scaffolding, or conversely, the level of independence of the learner, since the level of student autonomy and independence increases from structured to guided to open inquiry. Thus, we continue to advocate for the distinction between structured, guided and open modes of inquiry, but, in the light of Levy's matrix, would further divide these modes into the framing of 'information' or 'discovery'. Once this is achieved, and building on our research findings, it is possible to infer the extent to which the different types of inquiry are likely to strengthen the teaching–research nexus.

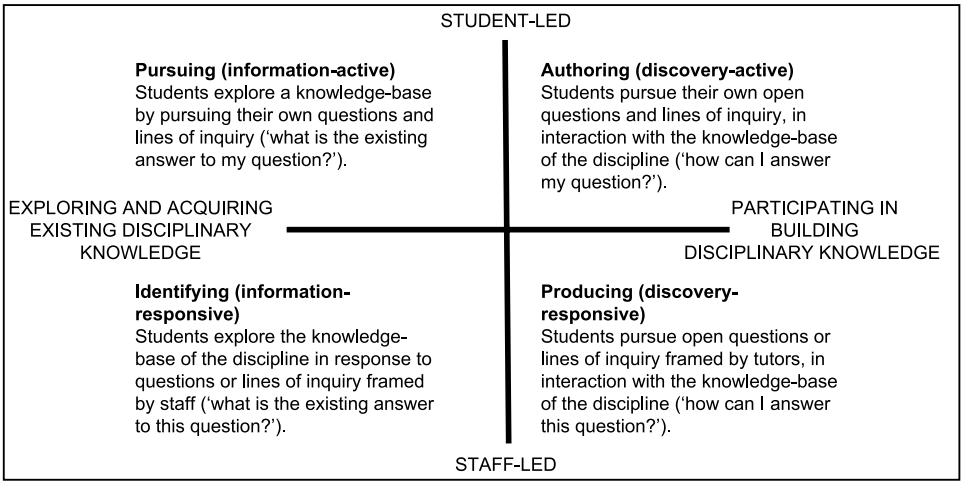

Figure 3. Matrix illustrating students' experiences of inquiry in the curriculum (Levy 2009).

Figure 4 shows a conceptual model of the linkages between the mode and framing of inquiry-based learning, as well as the teaching–research nexus. It is deliberately constructed in a stepped fashion to illustrate the scaffolding metaphor – the wider base is where teachers provide more support for learning of inquiry skills, whilst at the top students are more independent, and there is less teacher support. This model shows the interplay between the level of independence and the focus of learning, in terms of strengthening the teaching–research nexus. As the level of independence increases (or as the amount of scaffolding decreases), there is increasing choice regarding topic and method of study, an increased capacity to do research, an increased capacity for a community of practice to form, and consequently a strengthening of the teaching–research nexus (shown by the darker shading). Also, if the focus of learning shifts from concentrating on the *products* of research (hatched areas) to the *process* of research, there is also more potential for a strengthening of the teaching–research nexus. For

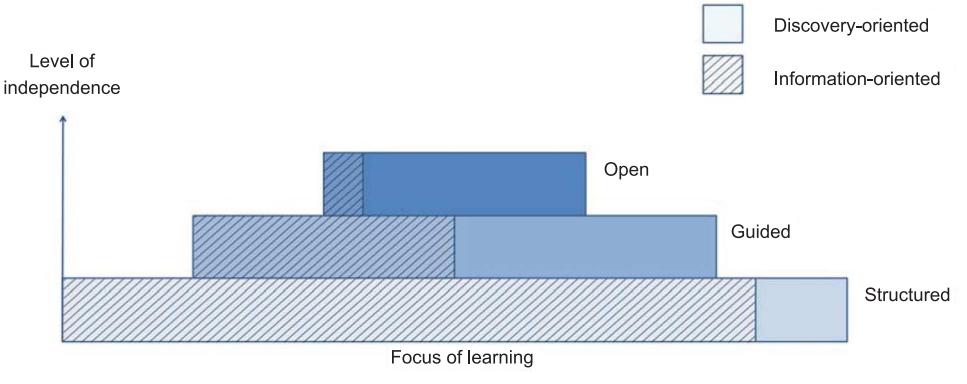

Figure 4. Conceptual model showing the relation between different modes and framing of inquiry-based learning and the teaching–research nexus. As the level of shading increases, so too does the strength of the teaching–research nexus.

structured inquiry, the focus of learning is mainly in an information-framing mode, whilst for open inquiry it is mainly discovery-oriented. Forms of problem-based learning that focus on existing knowledge would fall into information-oriented inquiry, generally under more structured and guided approaches. Importantly, there is less potential for such forms to strengthen the teaching–research nexus.

The podium shape of Figure 4 reflects our desire that graduates should attain the highest level or step, and experience open inquiry before graduating. One interpretation of the model is that structured and guided forms of inquiry should precede open inquiry. Indeed, some degree programmes are premised on this design (e.g. Spronken-Smith et al. submitted), and it is of particular value when first-year class sizes are very large, since structured and guided inquiry activities can be built into laboratory or tutorial programmes which typically have better staff to student ratios. By the final year of the undergraduate degree, with smaller classes, it may be logistically more feasible to offer open inquiry courses. However, in reference to progression from structured through to open inquiry, Healey and Jenkins (2009, 72) commented, 'it is too simple to conceptualise this as simply a linear process from highly structured to highly independent, although this may be the general trajectory'. They suggested that students are likely to benefit from having a fair degree of independence, through more open and guided inquiry approaches early in their degree, in order to build motivation. In subsequent years, structured inquiry can be used to further develop research skills, before returning to open inquiry in a capstone course. Indeed, if open inquiry was offered at first year, then there is the opportunity to enculturate undergraduates directly into the research culture of the institution, and into learning through research. Other researchers (e.g. Hodge et al. 2008; Levy and Petrulis 2007; Wood and Levy 2009) similarly advocate for open inquiry-based learning approaches, with appropriate support, early in the curriculum, and, as Justice, Rice, and Warry (2009) reported, this can lead to the early development of a range of research and transferable skills that stand students in good stead for the remainder of their university study.

If teachers are planning to use inquiry-based learning as a means to strengthen teaching–research links, they must be cognisant of the different manifestations of inquiry, and how these may influence the nexus. From our evidence the best chance of strengthening the link between teaching and disciplinary research was found to occur when open, discovery-oriented inquiry was used as the basis of course design.

Study limitations

From the cross-case analysis we developed a model (Figure 4) to show the relation between modes and framing of inquiry and aspects of the teaching–research nexus. Clearly this model needs to be tested, using a wider array of inquiry courses, to see if it is generalisable beyond these specific cases. Although we asked both students and teachers about their understanding of inquiry-based learning, and whether they perceived any links between inquiry teaching and their research, we did not probe them on their understanding of research, nor on their conceptions of knowledge. Yet we now suspect that much of the confusion around the definition of inquiry-based learning may be related to differing conceptions of knowledge and research, and the disciplinary context cannot be underestimated. Recent research has further explored student or teacher perceptions of research and teaching and links to curriculum design (e.g. Lucas et al 2008; Turner, Wuetherick, and Healey 2008), but there still remains

a need for research on both student and teacher conceptions of inquiry-based learning that encompasses perceptions of knowledge, research, teaching and learning.

Conclusion

Our analysis shows that inquiry-based learning can strengthen the teaching–research nexus, particularly when courses are designed using an open inquiry approach in which students generate a research question and complete the full inquiry cycle. The nexus is further enhanced if the focus of learning is discovery-oriented. Furthermore, if teachers are co-learners in the inquiry, this helps to facilitate an academic community of practice including both academics and students. Conversely, if the inquiry-based learning approach is structured and information-oriented, there is less potential to strengthen the teaching–research nexus. Defining inquiry-based learning continues to be troublesome but we have found 'structured', 'guided' and 'open' inquiry to be a useful categorisation, as well as Levy's (2009) distinction between 'information' or 'discovery-oriented' learning. The distinctions are important in order to promote the approach and to analyse the potential benefits and barriers associated with different types of inquiry-based learning. A broad brush approach which simply talks about 'inquiry' may miss the nuances associated with the different types of inquiry-based learning. For teachers new to inquiry-based learning, trying more structured forms may be advisable, but arguably the most benefit for student learning and for strengthening the teaching–research nexus comes from open inquiry approaches, particularly if they focus on discovery-oriented learning.

Our research, in typical inquiry fashion, has generated further questions. The conceptual model was developed from just three cases, and a range of types of inquiry-based learning should be scrutinised to see if the model is useful in a wider context. Conceptions of inquiry, knowledge, research, teaching and learning, and the relations between them, also need further probing in different disciplinary contexts.

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