SOFTLY, SOFTLY: INTRODUCING RESEARCH-LED EDUCATION INTO A SUCCESSFUL FIRST YEAR COURSE

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ABSTRACT
'If it isn't broken, why fix it?' How do we introduce innovative elements of research-led education into first year courses that rate well on student evaluations and appear reasonably successful? Such courses are often well established, tend to have a great deal of content that 'must' be covered, and deal with large numbers of students from diverse backgrounds. This paper presents an interim report of an action learning project, supported by the *Science and Mathematics network of Australian university educators* (SaMnet), to review a first-year biology semester-long course and introduce new research-led components that address threshold concepts in the discipline. Our approach involved necessitated a 'softly, softly' approach to bringing about change. In the first iteration of the reviewed course, subtle changes were made to introductory and practical activities, and a major change introduced in the last module, involving a sequence of small-group inquiry-based learning activities leading to a mini-conference on parasitology. The signs are that already students are benefitting from the revised approach, and especially reporting an appreciation of more feedback from lecturers and tutors.

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INTRODUCTION

> *While the term 'research-led teaching' now trips off the tongue of many … in research-intensive universities I have frequently found confusion between research-led teaching and researcher-led teaching; the assumption being that because the university is full of researchers, its teaching is,* ipso facto*, research-led* (Brew, 2002).

Research-led education (RLE) is a key focus for research-intensive universities, and the Australian National University (ANU) is no exception: 'By 2013, all ANU [undergraduate and postgraduate] programs will have clearly articulated the unique research-led elements of their education offerings' (*ANU by 2020* strategic plan). Since Brew's comment above, educational researchers and discipline specialists have tried many different ways of implementing RLE, but as Wilson, Howitt, and Wilson (2007, p154) explain, there remains 'considerable debate' on how best to teach undergraduates so as to help them develop generic research skills without 'compromising on [their] mastery of 'fundamental knowledge'. For this reason, while it may seem relatively easy to incorporate RLE into postgraduate and later year undergraduate science courses, it often appears a more difficult construct for those working with first year courses. Not only is there much basic knowledge that students must acquire in the first year to be well prepared for their continuing path of study, but such courses also tend to be well established, with large enrolments, and so may have less innate flexibility to accommodate change. This may be especially true when a course comprises several topics taught by different lecturers/researchers and appears reasonably successful in its present form: the prevailing motto may become 'If it isn't broken, why fix it?'.

This paper provides responses to what we believe is a more pertinent question in our research-focussed institution—'it isn't broken, but can it be more research-led?' We present an interim report of an action learning project to review a first-year semester-long course in human biology, and explore opportunities to introduce research-led components. This project was supported by the *Science and Mathematics network of Australian university educators* (SaMnet), which enabled a focus on collaborative and distributed leadership, and culture change (SaMnet, 2013). After a brief and selective overview of the literature in the key concepts that have guided our approach to this change process—namely research-led education, inquiry-based learning, threshold concepts, and scaffolding—this paper describes the introduction, in 2012, of one major and several minor changes to the first-year course (BIOL1008 *Human Biology*). The paper then discusses the outcomes so far, and considers future directions.

GUIDING CONCEPTS: A SELECTIVE LITERATURE REVIEW

RESEARCH-LED EDUCATION

With tertiary educators being encouraged to emphasise aptitudes such as creativity, synthesis, inquisitiveness, adaptability and an understanding of uncertainty, rather than proficiencies in memorisation, recall and specific technical skills, research-led education (RLE) could be described as an idea whose time has come. Many authors, internationally and in Australia, have reported the value of exposing undergraduates to inquiry-based learning through authentic research experiences (Barnett, 2005; Boyer Commission, 1998; Healey, 2005; Healey & Jenkins, 2009; Hunter, Laursen, & Seymour, 2006; Jenkins, Breen, Lindsay & Brew, 2003; Jenkins, Healey & Zetter, 2007; Kreber, 2006; Willison & O'Regan, 2007; Wilson et al., 2007).

While some see RLE as the learning activity that comes from an undergraduate contributing to novel research under the supervision of an active researcher (e.g. Boyer, 1998), others argue that research training is more effectively achieved through structured learning activities aimed at the acquisition of particular generic research skills (Hartberg, 2006; Holbrook & Devonshire, 2005). Healey (2005) has been particularly influential in conceptualising the diversity of RLE activities through a conceptual matrix that distinguishes between a teaching emphasis on research content versus research processes and problems, and an emphasis on students as audience or students as participants (Figure 1), although he uses the term RLE to describe a more constrained approach, whereas many authors use it in a more all-encompassing mode, as we do at ANU.

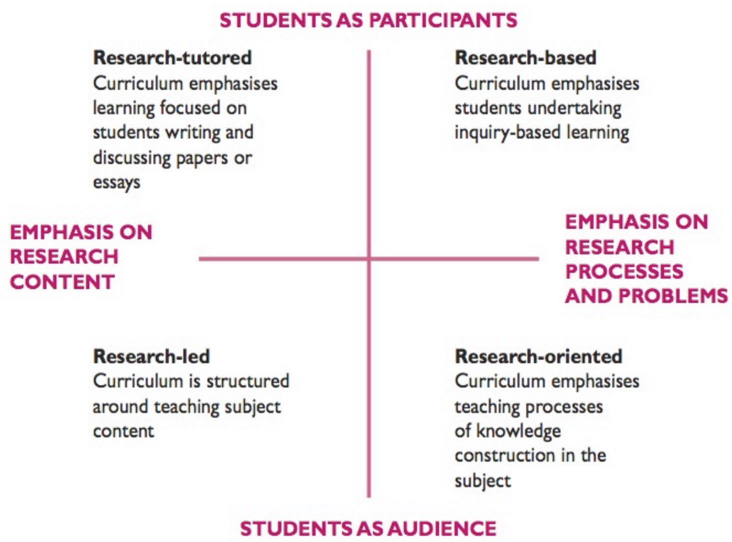

Figure 1: The 'Healy Matrix' showing the Research-Teaching Nexus (Healy, 2005, p70)

INQUIRY-BASED LEARNING

Student-centred teaching strategies that incorporate active learning, especially with an inquiry-based focus, improve learning outcomes (Armbruster, Patel, Johnson, & Weiss, 2009; Boud, Dunn, & Hegarty-Hazel, 1989). Kirkup (2013, p10) describes inquiry-based learning (IBL), or as he terms it, inquiry-orientated learning, as an approach that allows students to 'engage with questions that have no predetermined answer; develop and implement approaches to address those questions; work to refine their approaches … to enhance their methods/the quality of the data; gather evidence; and formulate and communicate explanations/conclusions based on that evidence'.

THRESHOLD CONCEPTS

Meyer and Land (2003, 2005) have defined threshold concepts (TCs) as the ideas that are central to the mastery of a discipline, but are often both difficult to teach and difficult to learn. As students grasp these concepts, they essentially pass through a disciplinary 'threshold' and become able to engage with the way of thinking, and often use of language, that characterises the discipline. The notion of TCs has motivated research on diverse aspects of teaching and student learning in many disciplines, including biology (Meyer, Land, & Baillie, 2010; Taylor, 2006). Taylor, Ross, Hughes, Lutze-Mann, Whitaker, and Tzioumis (2011, p1) identified the Biology Thresholds Matrix (University of Sydney, 2010), which 'illustrates the dimensions and inter-relations of these thresholds, and the relationships between student misconceptions and threshold concepts', empirically verified in Australian universities. Most relevant to the BIOL1008 course were the TCs of *variation*, *uncertainty*, *hypothesis testing, predictive testing*, and *equilibrium* (Taylor & Meyer, 2010; Taylor et al., 2011).

SCAFFOLDING
Vygotsky (1978) theorised that a student learns by moving from his or her 'actual developmental level, determined by independent problem solving', through a *Zone of Proximal Development* as he or she moves towards a 'level of potential development, as determined through problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1978, p86). At university, the latter includes 'direct and indirect assistance from other students, teachers, lecturers and researchers (Wass, Harland & Mercer, 2011). This assistance—support that a learner needs to accomplish a task that is outside his or her current level of development— has been likened to 'scaffolding' (Bruner, 1975; Davis & Miyake, 2004): as the learner moves forward with each part of a task, eventually to the point of mastery, the scaffolding becomes less needed and the learner becomes more autonomous.

TEACHING FIRST YEAR BIOLOGY
The first year experience at university is recognised as a 'make or break' time for many, so it behoves those teaching first years to take special care to make courses engaging, motivating and geared towards establishing good learning habits and skills (James, Krause, & Jennings, 2010). As with other sciences, first year biology classes are often large and content-oriented, but can also be intrinsically motivating with their potential relevance to students' own health and wellbeing. It is not uncommon, therefore, for student feedback on first year biology courses to be positive, even when qualitative and informal feedback suggests that students may have 'difficulty dealing with the quantity of information they need to learn, and in seeing the big picture amongst a wealth of detail' (Magierowski & Edwards, 2013). Wass et al. (2011) reported a longitudinal study of zoology students at a New Zealand university that looked at the development of critical thinking—a common intended learning outcome for undergraduates. With regard to first year students, who were taught in large general biology classes, the study found that the students' prior experiences, knowledge and cognitive abilities were not effectively acknowledged in the teaching; the students '*experienced a high-level of material scaffold in the form of course documents, textbooks, problem solving-exercises and discussions that were primarily aimed at the acquisition of factual knowledge',* with virtually no evidence of critical thinking skills being used or developed in that first year (Wass et al., 2011).

REVIEWING AND CHANGING THE COURSE

The course in question, *BIOL1008 Human Biology*, is divided into four, essentially independently-taught, modules (each comprising nine one-hour lectures) focussed on transmission of specific content in aspects of human biology that illustrate key life science topics, namely human nutritional needs and body weight; human reproduction; the relationship between human muscles and movement; and human infectious diseases and immunity. Interspersed with the lectures were five two-hour 'activities'. Activity A involved a discussion on ethics in human biology; Activity B demonstrated the Glycaemic Index through nurse-mediated sampling of students' blood before and after eating; Activity C focused on a video-informed discussion of human sexuality; Activity D involved practical measurements of students' heart rate, blood pressure and body temperature to assess muscle/nerve interactions; and Activity E centred on a video-informed discussion of the impact of infectious diseases on humans. All Activity sessions were run by the course co-ordinator (author JB) with Activity E supported by the module lecturer (author IF). Course assessment tasks were fairly standard: **five written assignments (each worth 10%) associated with the activity sessions, a mid-semester examination on the first two topics (25%), and an end of semester examination on the last two topics (25%), with a pass mark of 50% (with a 40% minimum in the exam components).**

Although the modules were taught effectively, and, according to course evaluations largely satisfied students (see 2010 and 2011 data, Table 1), informal talks with students suggested that they primarily focused on learning the content needed to pass each component without appreciating the bigger picture, namely how the fundamental concepts learned in each topic area are inherently linked, and represent key knowledge applicable across the discipline. Essentially, therefore, effective scaffolding towards relevant TCs was lacking: students could do well in the course, yet be no nearer becoming 'biologists'. From our engagement with the literature, it was clear that any new course activities should involve IBL activities, lead towards an understanding of the threshold concepts pertinent to first year biology, and include high levels of scaffolding between activities. Our review thus centred on the course learning outcomes and assessment tasks, seeking to improve constructive alignment between these, as advocated by Biggs (1999). We planned to replace some student discussion and written assessments with IBL activities that incorporated hypothesis development, basic literature research, evaluations of methods, statistical analyses, and presentation of results, in order to engage students more directly with generic research and reporting skills related to threshold concepts.

INTRODUCING CHANGE

We believed that, by making minor changes to Activities A, B, C and D, and their associated assessment, and a major change to the delivery and assessment of Activity E, we could help students to become more engaged with the course as a whole, and therefore more likely to reach better understanding of the relevant threshold concepts. In particular, given the university's emphasis on RLE, we hoped students would emerge with a more practically-informed understanding of basic scientific research methods relevant to human biology.

In 2012, in Activities A to D we introduced more scaffolding, and more cross-referencing to material already presented in the course. In Activity A, we re-focussed the discussion so that students would engage with the concept of ethical considerations as the key factor, and constraint, in any research on humans. This included introducing the notion of academic integrity, and hence plagiarism, which is relevant to the way the students must approach their own work. A new in-class assessment (worth 3%) asked students to apply their learned knowledge immediately to a small set of straightforward questions on plagiarism, ethics approvals, and consent forms, and to suggest an ethical dilemma and how it could be overcome (the latter acting essentially as a reflection on the discussion). Activity A also acted as scaffolding for Activity B (Glycaemic Index), where students were asked to give their informed consent to blood sampling. Our changes to Activity B itself were largely confined to adding discussion and assessment elements (take-home short answer paper, 10%) to incorporate more reflection on experimental design, methods, experimental error and suchlike than had been done previously, to ensure we introduced students to all aspects of research design, not just results.

Activity C involved stimulus material (a documentary video) and a facilitated discussion of human sexual behaviour. In 2012, students were helped to recognise that they were, in effect, developing working hypotheses from available evidence, and the facilitator helped the discussion shift towards exploration of how biologists would initially test a working hypothesis by reviewing the literature in the field. The requisite information literacy (IL) skills were then taught/reviewed, which led directly into an in-class assessment task (previously an outside-class task associated with Activity E) in which students use IL skills to test their working hypotheses against reported research findings. Activity D, the muscle-nerve practical, was a well-structured hands-on data collection exercise that remained largely unchanged except for clarifications in the associated assessment task, which increased the emphasis on data interpretation, statistical analysis and graphical representation (the latter supported by an optional post-session statistics tutorial).

THE PARASITOLOGY MINI-CONFERENCE

It was in Activity E, on human infectious diseases, that we saw the greatest scope for change, not least because the relevant lecturer was part of the SaMnet team, and had been toying with the idea of change for some time. The original class, with its 20% take-home short-answer assignment (including the IL tasks which had now been moved into Activity C), was replaced with a completely new activity—the parasitology mini-conference. The aim of this change was to introduce IBL opportunities in the form of a group desk-based research project spread over three weeks of class time, valued at 12% of course marks, and culminating in a group presentation assessed by both staff (80% weighting) and peers (20% weighting). The overarching intended learning outcome was that students would acquire knowledge and skills through an IBL approach to a topic in parasitology. Each aspect of the overall task was intended to achieve specific outcomes (Table 1) over the three sessions (weeks) of collaborative research and communication.

The new assessment task—comprising both the research and the presentation—was designed as a small-group (five student) collaborative activity that built on the skills students had acquired through the previous classes. The in-class research sessions were semi-structured, to ensure that even weaker students felt confident of making progress towards the presentation, although each group was required to plan its own approach and workload allocations. The research project was well scaffolded. First, each group selected a research topic: the discipline is very broad, and its focus on health and disease naturally attractive to students, so we presented a list of 17 pre-determined potential topics that varied in required knowledge (e.g. from the relatively simple 'What is attractive to a mosquito vector of malaria?' to the more challenging 'How is the pork whipworm (*Trichuris suis*) used to treat autoimmune disorders'), suited to the diverse student cohort (about 28% of whom were enrolled in psychology degrees, and 11% in non-science degrees). Either groups formed, then chose a topic together, or students chose a preferred topic and then grouped.

Table 1: Learning outcomes and learning activities for new Activity E

Intended learning outcomes Students will be able to demonstrate their capacity to:	**Learning activity to achieve this outcome**
Apply learned skills to a new situation	Using knowledge and skills gained from earlier parts of the course
Discriminate among relevant sources of information	Using accurate and reliable sources of information, with the aid of information technology, and referencing these appropriately
Plan and discuss presentation content with peers	Critically evaluating the information to be included in the mini-conference presentation, in collaboration with group peers
Synthesise an effective presentation	Designing the presentation, in collaboration with group peers
Communicate newly acquired knowledge	Explaining their group's findings on a particular parasitology topic to peers who had not researched that topic

We gave students refreshers in relevant communication skills and the use of scientific literature as resource material. Once formally registered in a topic, groups had a three-hour scaffolded and supervised class specifically to research their topic and prepare their presentation. The final presentations took place in the context of a multi-strand conference, each strand holding three groups. Students assessed peers with a previously-discussed marking rubric. A post-presentation 'party' acted as a debriefing/relaxation point.

OUTCOMES AND DISCUSSION

In our approach to re-interpreting the course from an RLE perspective, we planned a shift, in terms of the Healy matrix (Figure 1), from a focus on Healy's 'research-led and research-tutored' quadrants to the 'research-orientated and research-based' quadrants. Indeed, the course now essentially takes students on a scaffolded journey through all four quadrants, ending with the mini-conference as the essence of a research-based approach.

Lynch (2003) has described a valid concern that processes put in place to support accountability, such as student evaluations of teaching, may be inadvertently inhibiting academics from taking the risks of introducing innovations into their teaching. Certainly, it is not uncommon for educators who introduce what eventually becomes a successful course activity to be poorly rewarded by student evaluations in the first year of innovation: students with word-of-mouth expectations of teaching may be disappointed, surprised or concerned by changes, and any minor teething problems in the new approach may thus be reported in course feedback as major failings (Lynch, 2003; D. Martin, personal communication, 2011; M. Taylor, personal communication, 2011). We had always planned a change-focused evaluation for the 2013 iteration, so we had deliberately not included a significant evaluation strategy into our 2012 'softly, softly' approach: we wanted time to embed both the changes themselves and our understanding of their logistical impacts before we asked students' to spend time on additional feedback and evaluations (an approach in keeping with our university's policy to minimise 'over-surveying'). Nevertheless, our informal feedback from students, and the level of their engagement in all activity sessions, suggested high levels of satisfaction, and we were pleased to see students staying past 5 pm on the last day of semester to attend the mini-conference party.

The course was, however, subject to the usual university-standardised course evaluations, and it was thus very heartening—on the basis that 'no change is good news'—that almost all variables in the 2012 post-innovation course evaluation remained essentially similar to that from previous years (Table 1). The one exception was the students' evaluative response to the statement 'The feedback I received during the course supported my learning'. This showed a statistically significant improvement from 39.7% and 44.6% of students agreeing with the statement in 2010 and 2011 respectively to 78.5% agreeing in 2012 (Table 2). We believe this shift can be fairly attributed to the change in teaching style rather than some shift in the 2012 cohort's response, as there were no similar changes in the data for the other BIOL courses in the relevant semesters (Table 3). We are reluctant to analyse this finding in depth until our understanding can be informed with relevant data (which we intend to collect after this year's course iteration).

Table 2: BIOL1008 results from university standardised course evaluations 2010-2012

Statement on university standardised course evaluation	**2010** 250 enrolments 73 responses (29%)	**2011** 295 enrolments 71 responses (24%)	**2012** 310 enrolments 65 responses (21%)
	Mean rating of agreement (1=strongly disagree, 5=strongly agree) Per cent agreement (sum of categories 4 and 5)		
I had a clear idea of what was expected of me in this course	4.1 87.4%	4.1 77.5%	4.0 80.0%
The teaching and learning activities (eg. lectures, tutorials, field trips) supported my learning	4.1 88.8%	4.0 80%	4.1 86.1%
I had ready access to the learning opportunities provided in this course (eg. course notes, online materials, library resources, field trips)	4.3 91.6%	4.2 89.1%	4.3 89.2%
The assessment seemed appropriate given the goals of the course	4.0 78.9%	4.2 86.2%	4.0 86.1%
The feedback I received during the course supported my learning	3.1 39.7%	3.4 44.6%	4.0 78.5%
Overall, I was satisfied with my learning experience in this course	3.9 80.3%	4.0 84.4%	4.0 82.9%

Table 3: BIOL students' responses to statement on feedback in university standardised course evaluations 2010-2012

	2010	**2011**	**2012**	**Significance of change**
	Statement: *The feedback I received during the course supported my learning* Mean rating (SD), 1=strongly disagree, 5=strongly agree Per cent agreement (sum of categories 4 and 5)			
BIOL1008 *Human Biology*	3.1 (1.1) 39.7%	3.4 (1.0) 44.6%	4.0 (0.8) 78.5%	Significant[1]
All BIOL courses in the same semester	3.6 (1.1) 61.6%	3.6 (1.1) 61%	3.5 (1.2) 58.9%	Not significant

[1]One-way ANOVA model comparing the 2012 mean to an aggregate mean for 2010-2011 was overwhelmingly significant (p=0.000; T-value 39), providing strong evidence of an improvement in mean response in 2012.

However, our tentative hypothesis is that students were responding firstly to an enhanced awareness of what they should consider as opportunities for feedback (after an explicit discussion of the concept in the first lecture), and secondly to the intensive engagement with peers, demonstrators and lecturers during the preparatory sessions for the mini-conference. Wass et al. (2011) found that, in large first year biology classes, students 'tended to be relatively anonymous to teachers and most other students', and that, as a result, 'any peer relationship was valued for learning, even if this only served to confirm or validate factual knowledge'. We hypothesise that, by introducing IBL that encouraged much more peer and demonstrator engagement and feedback, we were creating richer peer relationships, and that our students acknowledged that this peer support provided them with effective feedback on their learning.

CONCLUSION

As Robert Hewitt has explained so clearly, 'Paradoxically, it is at times of chaos that you can make changes—if things are progressing reasonably well, it is harder to convince people to invest effort to improve or change' (M. Sharma, personal communication, 2013). This is undoubtedly one of the challenges for educators trying to introduce RLE and IBL into established courses, and one of the benefits of making these changes via action learning and distributed leadership, as supported by the SaMnet model. Although still at an early stage in course renewal, this SaMnet project is steadily working through the 'softly, softly' approach that we, as educators, felt ethically bound to take when working with students' 'live' learning experiences, even though the aims of change are worthy. The project aims ultimately to create well-scaffolded links among the course topics so as to give students both a holistic, rather than atomistic, path into human biology, and an introduction to self-directed RLE in the form of diverse IBL activities. The latter support different learning styles and lead inexorably towards relevant threshold concepts in biology. Moreover, with ever-increasing pressures on resources, this is being achieved without access to laboratory space. The team is planning additional IBL opportunities and a rigorous evaluation for the 2013 iteration, seeking not only to understand the impact of the specific changes effected in this course, but also any specific benefits from incorporating RLE into first year teaching.

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