Anna Wilson, *The Australian National University, Australia*
University of Canberra, Australia
Susan Howitt, *The Australian National University, Australia*

From the International Desk

Is More Always Better? An Australian Experiment with a Research-Intensive Undergraduate Degree

What happens when undergraduate students engage in multiple research experiences as substantial, graded components of their degree programs that contribute to their overall degree outcomes? In this article, we describe some of the effects of an Australian experiment in introducing a research-immersive undergraduate degree targeted at an elite cohort of high school graduates. Although the program has many positive aspects, we suggest that multiple undergraduate research experiences (UREs) may in themselves provide little more research preparation than has been found from single UREs, and that greater benefits may be obtained through a more structured, scaffolded approach where a deeper understanding of the discipline and the nature of scientific inquiry is developed in tandem with disciplinary skills and knowledge. While the focus of our research has been on UREs in a research-intensive university, we also consider factors that may affect what students learn from a URE more generally. This has implications for the provision of UREs in any institution or degree program.

Increasing Research Experiences in Australian Undergraduate Degrees

A range of different factors is currently driving an increase in the use of substantial research projects as graded components of Australian undergraduate and graduate degrees. These projects substitute for normal lecture courses. For one thing, many universities (ranging from research-intensive institutions to those with a more technical or professional focus) have developed policies and mission statements expressing a desire to forge stronger links between their research and teaching activities (Brew 2010). Perhaps the most immediately obvious way to integrate research and teaching is to bring students into academics' research activities via undergraduate research experiences. This development is in part a result of the recommendations of the widely read Boyer Commission Report (Strum Kenny 1998), which encouraged universities to offer all undergraduates the opportunity to engage in or experience research.

Another factor, in the increasingly "massified" market of higher education providers, is that having undergraduates working with high-profile research academics is seen as a promising marketing strategy. This practice allows more research-intensive institutions to claim that they provide a distinctive education. There is also a perception that research projects can provide a context in which generic skills such as critical thinking and communication, now emphasized for graduate attribute statements as much as disciplinary content-knowledge and expertise, can be productively developed. Finally, the newly revised Australian Qualifications Framework, which outlines standards required for the accreditation of different levels of tertiary qualification, stresses the development and acquisition of generic research-based and inquiry skills at both undergraduate and graduate coursework levels and encourages the use of capstone research units (Australian Qualifications Framework Council 2011). In response to all these factors, a number of Australian universities have introduced elite, research-based undergraduate degrees aimed at top high school graduates.

The Australian higher education sector, (discussed in a 2010 *CUR Quarterly* article by Angela Brew), has only 39 universities, but our experience may prove instructive. Brew discussed the invisibility of undergraduate research in the Australian system, but she focused on undergraduate research projects that fall outside the curriculum, not those within a degree program. Such projects are often offered in programs specific to a single department or linked to a discipline-specific funding body, contributing to their lower profile.

Elite, research-based undergraduate degrees have tended to appear initially within science faculties; elite undergraduate science degrees are now widespread across the sector, although a few institutions such as the Australian National University, the University of Western Australia, and the University of Western Sydney also offer them in other fields. Most of these special degree programs have stringent entry requirements, for example restricting entry to the top few percent of high school graduates. Students enrolled in these programs are usually expected to maintain a high minimum grade point average to stay in the degree program. Many explicitly aim to prepare students for research careers by introducing them to research early in their undergraduate degree, providing opportunities for students to do research and interact with researchers. These degrees commonly include one or more graded research projects, the opportunity to individually tailor the degree, academic mentoring, and/or opportunities to take special courses.

Research Experiences Assessed for Grading

In contrast to earlier international articles that have considered a range of inquiry-learning activities (Jenkins and Healey 2010; Spronken-Smith 2010; Vajoczki 2010), we focus on semester-long research projects in which the student is supervised by a researcher, as this type of URE is common in these elite degree programs. Typically, the undergraduate research project substitutes for a normal lecture course, accounts for 25 percent of a full load, and is done while the student is at the same time taking other courses delivered in a more conventional mode. Although graded undergraduate research experiences have been available for a long time in many universities, they have typically not formed substantial components of degree programs. In Australia, such research experiences have been available usually only as an option for a limited number of high-performing students in at least their third year of study, after students are perceived to have developed a substantial body of disciplinary knowledge and expertise. The undergraduate research experience has been aimed at encouraging future entry into an advanced research degree rather than being explicitly focused on developing generic research skills.

In some cases, the new degree programs encourage students to undertake research experiences throughout their degrees, even in their first year, as in the program we describe below. This approach is therefore different from both traditional third-year projects and the intensive capstone research projects carried out at the honors level in the Australian and United Kingdom systems, which are more likely to be undertaken full-time. There is also a marked contrast with summer research or internship projects, which are often ungraded and viewed as extracurricular activities. The changes within the Australian higher education system outlined above have resulted in an increasing prominence for graded undergraduate research experiences, whether in elite degrees or other contexts, making further investigation of their benefits timely.

While there has been a substantial body of research into the benefits of introducing undergraduates to research experiences and practice, most studies have focused on research projects undertaken through summer research or internship programs (Hunter et al. 2006; Kardash 2000; Lopatto 2004; Russell et al. 2007; Seymour et al. 2004). There has been little investigation into the impact of locating the research experience in a different context, where it is done for credit, is graded, and is carried out together with other coursework. To explore some of the issues that may arise in a research-immersive, elite undergraduate degree, we describe some of the results of our studies of the Bachelor of Philosophy or PhB (Science) at the Australian National University (ANU). The degree is one of the first and most intensive research-based undergraduate degrees introduced in Australia.

Institutional Context

The Australian National University is a highly research-intensive university with a small undergraduate population. The new degree was initially offered in science in 2003 as an alternative to the bachelor of science (BSc) program and has since enrolled approximately 30 to 35 students each year. Table 1 compares the two degrees. Students in the PhB must undertake at least three semester-long research projects, under the supervision of an expert researcher. This often entails the student being given a small project that fits within the overall research program of the researcher. Which of the project activities are assessed for grading is negotiated between the student and supervisor but typically include a report, a lab notebook, and a seminar.

Table 1. Comparison of the Bachelor of Science (BSc) and Bachelor of Philosophy (PhB)*

BSc	PhB
24 courses, which can include 1 or 2 optional undergraduate research experiences (UREs)	24 courses, which must include 6 research-based courses (at least 3 UREs and up to 3 extensions to normal lecture courses)
Open to top 20% of high school graduates	Open to top 1% of high school graduates
Optional honors (fourth) year project	Compulsory honors (fourth) year project
No grade criteria	Students must average 80% each semester
Defined majors	Flexible degree structure
No mentor	Academic mentor for each student
No special activities	Special activities such as introductory camp and annual conference

*For more details on the program structure and student cohort, see http://studyat.anu.edu.au/programs/4660HPHB%20%20;overview.html and Newitt (2007)

Because of the research-intensive nature of the university, many ANU academics hold research-only positions and have little or no conventional teaching experience. At the time of the introduction of the PhB, research-only academics outnumbered teaching and research academics by about four to one in the science faculties and were often housed in separate departments. These academics entered the pool of supervisors available for undergraduate research projects, however, raising issues of how to integrate into the teaching program those academics whose prior experience was only in the conduct of research.

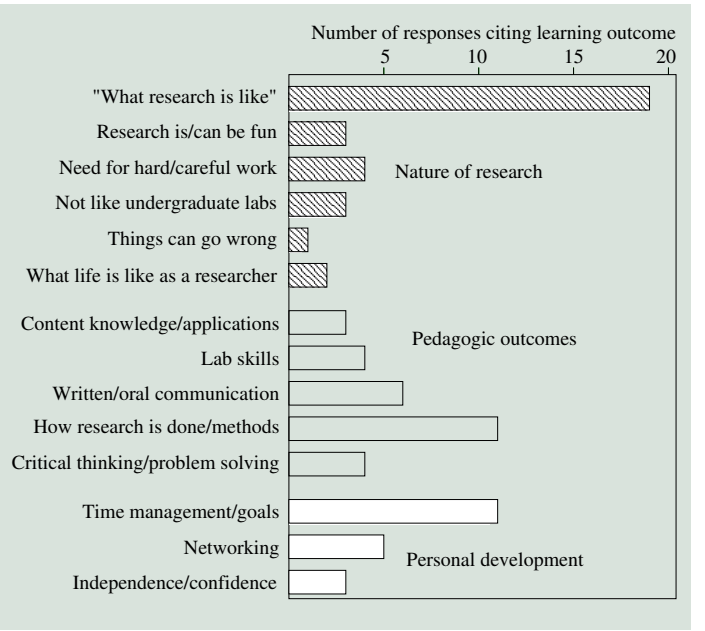
Perceptions of the Aims and Outcomes of UREs in an Elite Degree

A variety of issues may arise when undergraduates' research projects are graded or form substantial curricular components. For example, such projects often involve a one-on-one relationship between student and supervisor and are thus costly to run in terms of academics' time commitments. Evidence from studies of non-graded research experiences suggests that learning outcomes are variable and that student experiences depend significantly on supervisors (Hunter et al. 2006; Kardash 2000; Lopatto 2004; Russell et al. 2007; Seymour et al. 2004), which in turn raises issues of equity when such experiences occur within a degree program. In addition, there are serious questions about quality and standards in both learning outcomes and grading, as well as questions about comparability of projects to more conventional coursework.

We were also particularly interested in whether the learning outcomes and benefits identified by students were different in the context of a degree explicitly aimed at future research preparation and that involves multiple research experiences, compared to studies of students who had undertaken a single research project. Studies of the latter generally find that although students respond positively to a research opportunity and report that they learn "what research is like," the other learning gains they report are highly variable and often do not include higher-order thinking skills (Hunter et al. 2006; Kardash 2000; Lopatto 2004; Russell et al. 2007; Seymour et al. 2004). Both academics and students involved in the PhB program have been surveyed about their attitudes toward undergraduate research and the learning outcomes in the program (Howitt et al. 2010; Wilson et al. 2011; Wilson et al. 2013). Thus we are starting to gain a picture of the effectiveness of the research-focused undergraduate degree, as well as potential unintended consequences of such a degree structure.

Somewhat surprisingly, our survey of students in the PhB degree (Howitt et al. 2010) gave very similar results to surveys on students in non-graded, single research experiences. When asked about the most important thing learned in their research projects, they state that they enjoy the experiences, learn about research, and gain confidence in their ability to do research. However, despite undertaking between three and six research projects, they still rarely identify gains in critical thinking, hypothesis generation, and testing or experimental design (Figure 1). Similar to earlier studies, students also report that quality of supervision is the major factor in determining their enjoyment of their exposure to research, with a large proportion of students attributing their best and worst research experiences to the quality of supervision. The major difference between what students report learning from the PhB and earlier studies is that PhB students identify gains in time management, organizational skills, and their ability to take responsibility for planning (Figure 1). This appears to arise from the requirement that they plan and organize their research experiences, learning to divide their time between the research and their other courses. While such skills are essential to a successful researcher, it might have been expected that other research skills would be identified more frequently by students undertaking multiple, sequential, research-based units.

Figure 1. The most important learning outcomes identified by PhB students from their undergraduate research experiences. Students were asked an open-ended question about what they had learned and their answers were categorized (as described in Howitt et al. 2010).



These results raise the question of why students fail to report gains in higher-order research skills, despite being involved in research in each semester of their degree. From the initial study, it was not clear whether students do not gain these skills or simply that they do not identify such skills and therefore fail to report them as learning gains. To start to answer these questions, we have investigated both students' and project supervisors' perceptions of the aims of the degree and of the research components (Wilson et al. 2011; Wilson et al. 2012). We found that perceptions varied widely, with students and supervisors giving aims for both the program and individual projects that were not directly related to developing higher-order research skills.

Figure 2. The purpose of the PhB degree, as seen by students and supervisors. Students and supervisors were separately surveyed with an open-ended question and their answers were categorized (as described in Wilson et al. 2011; Wilson et al. 2012).

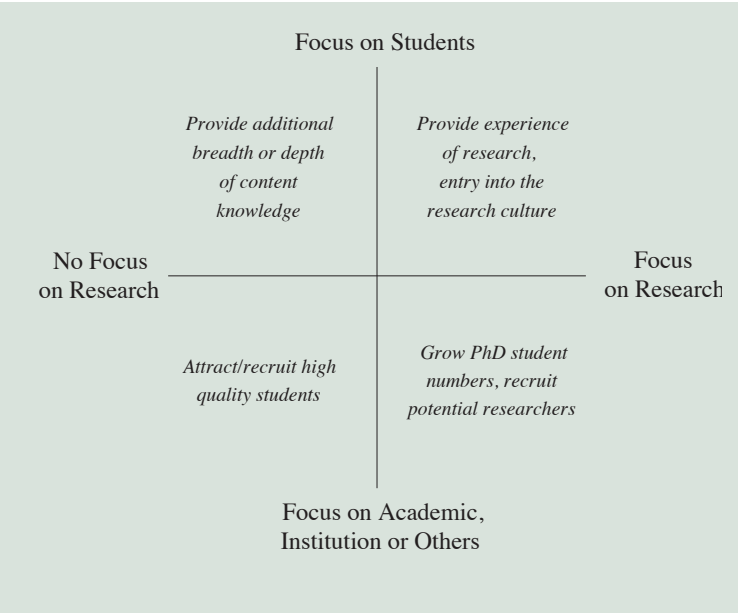
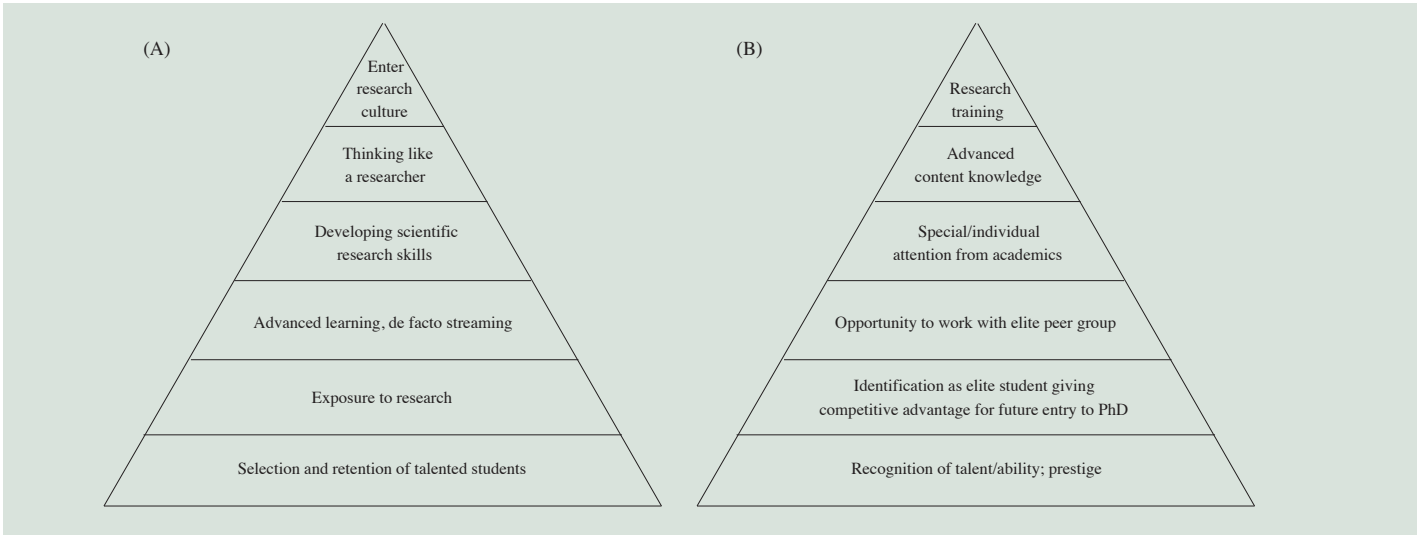


Figure 3. A. Aims of undergraduate research experiences as perceived by supervisors. B. Students' reasons for enrolling in the PhB degree. Categories were derived from answers to open-ended survey questions (Wilson et al. 2011; Wilson et al. 2012).

While the perceptions of supervising academics and students about the overall aims of the program (summarized in Figure 2) showed similar variation, there were also some differences between staff and student perceptions of the purposes of individual research experiences (summarized in Figure 3).

While some academics (Figure 3A) did see their role as integrating the student into the research culture and providing experience in a range of research skills, other academics had more specific aims for the research experiences they offered. Our results suggest that many had a hierarchical view of the development of research expertise, with content knowledge and motivation required first, followed by the development of analytical and technical skills, finally leading to the student's ability to engage in research.

Students in the PhB program had similar views, but in addition saw value in belonging to a cohort of high achievers and obtaining prestige through graduating with an elite degree (Figure 3B). Students whose main reasons for enrolling in the degree were related to prestige tended not to identify special learning opportunities or benefits from their research experiences beyond confirmation of their elite status. Thus, it seems that at least part of the reason that some students do not report learning higher-order research skills is that they do not recognize that research experiences could provide them. While supervisors potentially have a role in helping students to develop a broader view of research, some of the supervisors also appear unaware that generic research skills could be an explicit learning outcome of the research experience. This is by no means true for all students and supervisors, with many well aware of the opportunities for learning research skills provided by the research projects. However to ensure equity between the experiences



and to best promote and facilitate student learning within them, it appears that some effort needs to be made to raise both supervisors' and students' awareness of higher-order learning opportunities.

Factors Affecting What Students Learn from Research

These findings suggest that both academics' and students' perceptions of the value and nature of the research experiences may be limiting the learning outcomes that students recognize or even achieve. This raises an important issue: Are graded experiences the best way to integrate research skills into the curriculum? While the majority of students are extremely positive about their experiences in the PhB, it is not clear if the enthusiasm and motivational benefits from doing multiple projects are greater than those from a single research experience.

Where a project replaces a conventional course, students and academics might justifiably hope that identifiable learning outcomes will be achieved. Brew (2010) notes that although research experiences could be seen as a mechanism to integrate research and teaching, they usually fall outside the standard curriculum. Academics who are used to supervising projects in summer research programs or who are completely unused to project supervision may need significant levels of support in designing appropriate learning outcomes and in ensuring that project activities, grading criteria, and grading decisions are aligned with these. Because of their location within the research activities of the university and their focus on current problems or existing research programs, each individual research experience at ANU tends to be unique. Thus they are unlikely to receive the kind of careful cycles of curriculum design that may occur in established, repeated units of coursework.

As noted above, surveys of students doing research in different contexts show that supervision is of great importance in determining the success of undergraduates' research experiences. In a non-graded experience, poor supervision may result in students' feeling that they have wasted time; such supervision may even turn them against science. In a graded research experience, however, the quality of supervision could influence not only the quality of the experience but also the learning outcomes and the student's grade. This could have significant consequences for this cohort of students who need to maintain high marks to stay in an elite program, with many also aiming to meet requirements for prestigious postgraduate scholarships.

Even an "ideal" research experience, in which appropriate factors are considered in the design of the project and the level of support provided, may not be the best way to develop research skills. The Boyer Commission's report (Strum Kenny 1998) proposed radical curriculum change as a way of achieving better student learning outcomes in relation to research preparation. This included a variety of inquiry-learning, collaborative, and interdisciplinary activities from the first year on, in addition to the inclusion of a capstone research project. While the aim was to capitalize on the research-intensive nature of many universities so as to provide a unique education for undergraduates, integrating the research arm of the university into teaching was envisioned in a clearly defined context within a structured curriculum that also included significant pedagogical reform. However, while many universities have adopted the rhetoric of the Boyer report to justify including some research experiences or inquiry-learning activities (see Healey and Jenkins 2009 for excellent examples), few universities have fully implemented its recommendations. The somewhat ad hoc nature of the PhB—in which each research experience undertaken by a single student is likely to be with a different supervisor and is rarely built on skills acquired in previous experiences—is a very different model.

Another factor to consider in curriculum redesign for research skills is that undergraduate students, as novice researchers, may lack the expert viewpoint required to fully participate in the intellectual aspects of original research. An expert can readily identify problems and areas for further analysis, whereas a novice has little experience in ranking different sources of information and identifying what is relevant. Trying to develop research skills by placing students in this position has been characterized as confusing the epistemology and the pedagogy of science (Kirschner et al. 2006). While expert scientists take the nature of scientific inquiry for granted, undergraduates may need much greater support to develop an understanding of the nature of research than they typically gain from a single semester-long project in which they are trying to master both disciplinary knowledge and laboratory or analytical skills.

Practicing science and learning to practice science should be seen as distinct, with educational activities aimed at the latter designed to take into account the novice's lack of experience and content knowledge (Kirschner et al. 2006). If undergraduates are unable to fully appreciate the mindset of an expert researcher, it is not surprising that they do not gain higher-level thinking skills or that their views of science are quite resistant to change, with several studies reporting that exposure to research through a research experience does not always enhance students' understanding of the nature of science (Ryder et al. 1999; Schwartz et al. 2004; Thoermer and Sodian 2002). On the other hand, one of the things that students most enjoy from research is the feeling that they are participating in "real" science, so there clearly is a place for authentic research experiences in degrees aimed at research preparation.

Conclusion

The Boyer Commission Report (Strum Kenny 1998) advocated sweeping changes to the curriculum, aimed at developing students' lifelong learning skills in the context of a research environment. Our experience with the PhB degree has demonstrated that implementation of research experiences within a degree program, even without other components, has many benefits. Students enjoy the challenge and experience of research and their interactions with researchers. They become more familiar with the demands of research and many gain confidence, time management skills, and independence. However, it appears that implementation of multiple research experiences within a degree program does not, in itself, provide an effective way of teaching research skills and that learning outcomes are highly variable. A combination of different activities, in which students progress through different levels of inquiry-learning accompanied by frequent reflection and analysis, culminating in a capstone project that builds on their earlier experiences, may provide a better and more equitable means of preparing students for research. Such an approach can be offered by research-intensive and non-research-intensive universities alike, potentially opening up the benefits of undergraduate research experiences to a wider range of students.

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Anna Wilson

University of Oxford, Anna.Wilson@anu.edu.au

At the time of writing, Anna Wilson was deputy director of the Research School of Physics and Engineering at the Australian National University, where she worked with Susan Howitt on an Australian Learning and Teaching Council Innovation and Development Grant looking at ways of enhancing learning outcomes from undergraduate research experiences through reflective practice. Wilson also worked part time at the University of Canberra's Teaching and Learning Centre. She is now at the University of Oxford, in the Oxford Learning Institute.

Susan Howitt is deputy head of the Biology Teaching and Learning Centre at the Australian National University, where she is working on an Australian Learning and Teaching Council Innovation and Development Grant looking at ways of enhancing learning