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Connecting expectations and experiences of students in a research-immersive degree

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Recent studies of undergraduates engaged in authentic research have suggested that students may benefit in a range of different ways from such experiences. However, these same studies have also shown significant variation in the extent and universality of these benefits. This article investigates the impact of one potential source of variation in perceived benefits: students' prior expectations of what research experiences might offer. The authors' surveys of students enrolling in a research-immersive undergraduate science degree indicate a range of anticipated benefits from or opportunities within the degree, only some of which address preparation for research or the development of generic research skills. The benefits that students report gaining from their involvement in the program appear to be constrained by these prior expectations. The authors suggest that these constraints may be connected to students' understanding of the nature of science and scientific research.

Keywords: undergraduate research experiences; student expectations; motivation; research training

Introduction

In this article, we explore how undergraduate students' expectations may constrain the benefits they identify from engaging in research. The development and nurturing of connections between research and teaching have become key components of rationales for the purpose of the higher education sector (Brew 2006). A perceived connection between high-quality research and high-quality teaching is often raised in justifying both the increasing focus on research as the primary activity of universities, and the funding of research through income generated from teaching. This elevation of research leads in turn to research training being seen as the pinnacle of an academic education, leading to many research-intensive universities seeking to differentiate their educational offerings by including a strong research focus at the undergraduate level (Hu, Kuh, and Gaston Gayles 2007; Krause et al. 2008).

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This internally-driven tendency is amplified by external drivers focusing on employability and generic skills. The acquisition of content knowledge is no longer so strongly valued for its own sake, partly because 'facts' are now easily and instantly available via increasingly powerful Internet search engines. Instead, skills that are likely to be valued in a university graduate include inquisitiveness, a logical approach to planning and problem-solving, critical thinking and evaluation, self-evaluation and communication skills. Since these desired generic skills are in many respects similar to those needed to become an effective researcher, the inclusion of research-focused components in undergraduate degrees, particularly in the form of authentic research experiences, provides an apparently easy route for research-intensive universities to improve the generic skills of their graduates, while at the same time increasing the integration of their research and teaching activities.

Several studies of undergraduate students' experiences of research have suggested that students recognise a variety of benefits, such as higher awareness of research in their institution, improved communication skills and improved ability to work in a team (see, for example, Howitt et al. 2010; Hunter, Laursen, and Seymour 2006; Kardash 2000; Laursen et al. 2010; Russell, Hancock, and McCullough 2007; Seymour et al. 2004). However, these studies also found that only a small fraction of students reported gains in higher-order critical thinking and research-specific skills, such as experimental design, hypothesis testing and an awareness of the contingency of knowledge, even when multiple research projects were undertaken as part of a research-immersive degree (Howitt et al. 2010).

There is thus mounting evidence, both that a range of benefits from research experiences may be recognised by students, and that some students report more limited gains than others. However, there has been little attempt to determine what is responsible for this variation – whether it is the result of differences in the research experiences of individual students, differences in supervision or differences in the predisposition of students towards their research experiences. In a previous article, we suggested that some of this variation may be a result of the varying intentions of academics in supervisory roles (Wilson et al. 2011), since the perceptions of the purpose of undergraduate research experiences held by academics also show wide variation. It is also likely that the structure and content of each research experience is likely to affect perceived gains. For example, if a student is engaged in a small part of an ongoing investigation, focusing on a particular stage of experimental preparation or observation, data analysis or modelling, they may be less likely to develop a coherent sense of scientific or research processes in action than if they undertake a smaller, self-contained project, where they are involved in planning, execution and subsequent data analysis. On the other hand, smaller-scale projects may lack the depth, disciplinary integration and sense of being part of a bigger picture developed in larger projects. In the present work, we suggest that students' prior expectations may also be a significant factor in determining the perceived benefits of engaging in research as an undergraduate.

Context for the research

This article presents findings from an ongoing study of students and academics involved in an elite, research-immersive science degree program at a research-intensive Australian university. Like many other institutions competing for funding and prestige in the global higher education marketplace, the university sought to strengthen its international reputation, and to attract high-achieving domestic and international students

into both undergraduate and graduate programs, through the introduction of specialist or elite programs. A natural focus for the creation of a distinctive identity came with the availability of a relatively large pool of research-only academics who could supervise and resource research projects connected with their own research programs. The university, therefore, created an elite degree, ostensibly aimed at training the research leaders of the future. This program provided the university with a means to distinguish itself from its peers, and simultaneously met some of the recommendations of the Boyer Commission report on undergraduate research, in particular that research-intensive universities capitalise on their research strengths by offering undergraduates opportunities to engage in research (Strum Kenny 1998). The elite degree is explicitly marketed as an avenue to PhD research, with the title PhB (Bachelor of Philosophy) intended to reflect this.

The degree comprises a four-year program, including between three and six separate, single-semester research projects in the first three years and a research-based final year. Neumann (1994) proposed a framework describing the teaching–research nexus in terms of three levels: tangible, intangible and global. The PhB degree can be seen as exemplifying all three, with research experiences intended to transmit knowledge and skills (the tangible level), and attitudes and approaches (the intangible level), through projects driven by the research strengths of the university (the global level). The program (including structure and student demographics) is described in detail elsewhere (Newitt 2007). It was launched in the science disciplines in 2003, and has subsequently been extended to disciplines in arts and humanities, with a modified version offered in engineering. At the time of this study, there were significant student numbers in the later years in the science-based program only.

Although the PhB is rare in its research intensity, it is characteristic of a direction being increasingly taken by universities in the USA, Europe and Australasia (Krause et al. 2008). The desire to marry the teaching and research activities of a university within the undergraduate program has led to a variety of approaches to making education more ‘research-led’, as has been documented in the recent work of Healey and Jenkins (see, for example, Healey and Jenkins 2009; Jenkins 2004; Jenkins, Healey, and Zetter 2007). However, the dominant mode of introducing undergraduate students to direct experience of research remains through undergraduate research projects, mostly via vacation scholarships and internships.

The university is a member of the Group of Eight, the Australian equivalent of the Russell Group in the UK or the Ivy League in the USA. The undergraduate body consists of generally high-achieving students, of whom in the sciences typically 20% would go on to undertake a higher degree by research. The explicitly-stated aim of the PhB program is to provide a research-based education for elite students to better prepare them for future research careers; around 50% of the PhB cohort go on to undertake a PhD, although a significant fraction in the biosciences trasfer to graduate medicine. Entry into the program is restricted to the top 1% of school-leavers, as measured through the Australian school-leavers ranking system, which assigns a number rank indicating each student’s position within their national cohort.

The program provides students with opportunities to participate in the university’s research activities from the beginning of their undergraduate degree. A high level of flexibility in the choice and sequence of courses means that the degree is also somewhat self-directed, echoing some of the intentions of the independent study programs introduced in the UK in the 1970s (Percy and Ramsden 1980). However, in the present case the flexibility is expressed as choice among pre-existing options, rather than genuinely

student-developed curricula. The first three years of the program include at least six research-focused experiences (contributing 25% of study time) in areas chosen by the student with advice from an academic mentor. These experiences replace standard lecture courses in the core degree. The broad aim is that these experiences should provide substantial research training and experience. The program requirements stipulate that at least three of these courses should take the form of semester-long research projects which are designed and supervised by active researchers. A more substantial research project is undertaken in the fourth (honours) year of the degree, counting for 50–100% of the student's grade in that year, depending on discipline. Students must maintain a high distinction grade average (requiring marks averaging 80% or above) in science and related courses throughout the degree, or be transferred into one of the university's other science degree programs.

The focus of the present work is the research projects taken in the first three years of the degree, when the projects compete with more substantial conventional coursework loads for the students' intellectual attention, rather than the more intensive honours-level project completed in the final year.

Approach

The present work focuses on: (1) variation in the students' reasons for choosing to enrol in this research-immersive degree, (2) the types of benefit they anticipate, and (3) the connections between anticipated and experienced benefits. In order to obtain data from a significant fraction of the students, we chose to use anonymous, open-ended surveys, available online over a four-week period to allow the students to provide considered responses. At the time of the study, the total number of students enrolled in all years of the program was approximately 110, all of whom had commenced university study immediately after completing high school or equivalent. A total of 51 students responded; 9 respondents were in their first year of study, 16 in their second year, 21 in their third year and 5 in their fourth year. In the following, students are identified as S1–S51 and their year of study is given.

The surveys were completed in the first quarter of the academic year, so those students in the fourth year of the program had not experienced any substantial or intensive (honours level) research. The responses to the questions were thus informed by the students' experiences of research in the form of single-semester projects, carried out in parallel with standard coursework, rather than the more extensive and immersive research experience that characterises the honours year in Australia (Kiley et al. 2011).

The students were asked a series of open-ended questions about their experiences of the program. These included questions focusing on their reasons for choosing the PhB, their perceptions of the aims of the program, and what benefits they perceived themselves as gaining through the research projects they had undertaken in the first three years of the degree, and through contact with project supervisors and mentors. Respondents also indicated the number of research projects and extension activities they had undertaken.

Our analysis was aimed at uncovering the range of perceptions of students enrolling in the degree, rather than the frequency with which a particular point of view was evident, and the ways in which those perceptions varied. A qualitative approach was therefore appropriate. We adopted the constant comparative method (Maykut and Morehouse 1994, 127–48) to identify recurring themes within the data. Initially, the responses were grouped by question, and each set of responses was read with the

intention of identifying major themes and differences in students' perceptions and experiences. Common phrases and ideas were identified and used to develop categories describing the range of these perceptions and experiences. This process was carried out independently by two of the authors. There then followed an iterative process of rereading the responses and refining the categories, which was repeated until a stable set of categories emerged.

In the following, we describe students' reasons for choosing to enrol in the program, focusing on their expectations in terms of special benefits. Six different categories emerge, which fall into three groups with contrasting foci. We then examine the relationships between anticipated and perceived benefits. Finally, we discuss possible factors influencing these relationships.

Students' reasons for choosing to enrol in the program

At the time of the surveys, the degree was coming to the end of its first full cycle and so although *marketed* as an elite program, it had not had time to establish a reputation or brand recognition based on the quality and destinations of graduating students. Students enrolling in the program were high-achievers, in the top 1% of school leavers, and would have been likely to gain entry into undergraduate programs in many internationally competitive institutions. Instead, they chose to enrol in a relatively unknown degree, the very title of which was for the most part unrecognised outside the university. The lack of brand recognition is evident in comments such as, 'I didn't really know much about it before I got in – I don't know if this has been remedied but I found very little information on it at the time' (S31, 2nd year). Students also expressed concern that the program 'is under-recognised outside of [the university] and is misinterpreted as a philosophy major, due to the title Bachelor of Philosophy' (S3, 1st year). As one third-year student put it, 'What I am a bit worried about is prospective employment – do employers even know what a "PhB" is?' (S7, 3rd year). Enrolling students can, therefore, be seen as pioneers, risking the educational capital already accrued in their excellent school records by striking out into unknown, uncharted territory.

While most studies have suggested that undergraduate students generally enjoy engaging in research (Howitt et al. 2010; Hunter, Laursen, and Seymour 2006; Laursen et al. 2010; Russell, Hancock, and McCullough 2007; Seymour et al. 2004), what motivates them to do so in the first place is unknown. In the majority of previous studies, the research projects have been undertaken as optional extras, without the pressure of assessment or credit towards a degree. In such circumstances, students may be expected to see these opportunities as fun, as well as providing a good indication of interest and ability on a curriculum vitae. But when the project is assessed and the score counts towards the student's future grade point average, why might students take the risky choice of stepping out of the comfort zone of conventional learning and assessment, in which they may have a proven track record of success? It might be expected that students enrol in the PhB because they anticipate some special opportunities during or arising from the degree. The responses to the survey question on why students chose to enrol suggest six main categories in this regard:

(1) Students focused on prestige and identity, but had no clear expectations of special opportunities.
(2) Students focused on prestige and identity, and expected special benefits in the future, after completing the degree.

(3) Students anticipated benefiting by working with an elite peer group.
(4) Students expected to receive special, individual attention from academics.
(5) Students anticipated acquiring advanced disciplinary content knowledge.
(6) Students anticipated opportunities to learn research skills and ways of thinking.

These categories are described in more detail below.

The data suggest that, despite the research-immersive character of the special activities which distinguish it from the standard BSc, the research focus of the degree may not be a primary reason that many students enrol. In the sample surveyed here, a little less than one-third of students described opportunities to learn research-related skills or gain experience in research as a motive to enrol. The perception that the degree would offer greater breadth and depth of knowledge was equally important, as was its restriction to an elite cohort of high-achieving school-leavers, and the expectation of special access to academics and facilities not usually available to 'normal' undergraduate students. It is these factors which appear to entice students to undertake the degree, more than the expectation of acquiring new, research-related skills or ways of thinking.

Category 1: Focus on prestige and identity, with no articulated expectation of special opportunities

A surprisingly large number of students did not refer to any anticipated benefits or special opportunities within or following the degree. Many students described choosing the degree simply because it was targeted at outstanding students. Responses in this category refer to the high entrance requirement and the associated prestige of being accepted into an elite program. They relate to neither the research focus of the program nor any anticipated learning opportunities. Students described motivations for enrolling as including 'the fact that it was targeted at the brighter students' (S35, 1st year), 'it seemed prestigious and had a high cut-off compared to my other options, so I felt that I was making "better use" of my [school-leavers' rank]' (S19, 3rd year), 'Well, a science degree has an entrance score around 80 and I got over 99 … What's the point of working so hard for 2 years if I could have slept through all my classes and still got into the same degree?' (S37, 2nd year). Whilst one might interpret the idea of 'making good use' of a score as indicating expectations of some sort of special experience, this category of response focused on specialness in terms of prestige and identity, rather than special opportunities or experiences. The scholarship offered to some particularly high-ranking applicants was also appreciated. For some students, the entrance requirement and the scholarship were the only reasons for choosing the degree: 'I got a good score, and there was money on offer. That's basically it' (S33, 3rd year).

Category 2: Focus on prestige and identity – anticipated benefits come after the degree

Some students saw the potential for future advantage associated with an elite degree, as is evident in responses such as 'it sounded quite prestigious, so it would help me stand out above the others when it came to PhD opportunities or employment' (S12, 2nd year), and 'the PhB has a lot of prestige associated with it meaning it will (hopefully) be a marketable degree' (S49, 4th year). This feeling was sometimes combined with the

strong sense of not wanting to waste a high school-leavers' rank, as evident in the following advice to the university:

> the requirements for the [standard degrees at the university] are simply too LOW to attract high-achieving students! … high-achieving students who get 99+ in their [school-leaving rank] have the notion that coming to [the University] will be a waste of their secondary [school] achievements! … with the PhB, with a much higher entry requirement, more high-achievers are lured with the prospect that getting into the PhB will distinguish you from 'the rest' (which isn't a nice way of putting it, but it's the truth). (S5, 2nd year)

Other students saw the degree as a direct pathway to a PhD, indicating that anticipation of a future research career was an important motive in their choice. Reasons given for enrolling included 'the chance of getting into top research field' (S27, 1st year), 'wanting a career in scientific research' (S18, 2nd year) and 'I was firmly decided that I wanted to go through to a PhD' (S13, 3rd year).

Category 3: Opportunity to interact with an elite peer group

For some, a factor in their choice of degree was the anticipated peer group: 'opportunity to work and learn with peer group of outstanding ability' (S3, 1st year); 'I had some friends entering in to it, whom I admired. Further, the small candidature and the close-knit property [*sic*] I thought it would have appealed to me' (S4, 1st year). Students anticipated that the degree would 'bring together like-minded people (the cream of the crop?)' (S35, 1st year). This factor was evident only in responses from students in their first year. In common with the previous two categories, the focus here is strongly on prestige and identity, but now through membership of an identified group.

Category 4: Opportunity to interact with elite researchers

Students were also attracted by the prospect of personal attention, connections with established academics and the expectation of special treatment. Reasons for enrolling included 'contacts made through mentor' (S3, 1st year), 'the promise of personal mentorship' (S19, 3rd year), 'greater contact with faculty' (S6, 2nd year) and 'the extra attention' (S12, 2nd year). As one student put it: 'Staff availability or staff/student ratio is a major discriminator between other Australian universities and [the university] … so the introduction of the idea of a mentor makes this degree stand out even more' (S5, 2nd year). As with the previous category, the appeal of the program comes from the identification of the student as a talented individual, this time leading to expectations of individual attention and recognition from academic staff, and greater connection with the academic community.

Category 5: Opportunities for advanced coursework and acquisition of content knowledge

Some students indicated an expectation of special learning opportunities that had little to do with experiencing research or gaining research-related skills. Instead, they focused on increased challenge, breadth or depth in coursework. Students chose the degree because 'it was an advanced version of the course I wished to do' (S29, 3rd year), '[the PhB] allows me to do a broader range of subjects' (S17, 1st year) and the degree gives 'the ability to study things not usually in the curriculum' (S28, 2nd year). There was a strong emphasis on the flexibility of the program (which allows students to skip prerequisites

and take courses outside science). One student responded very positively to 'the flexibility and tailor-made nature of the degree … Flexibility is probably, in my opinion, one of the highest valued characteristics of any degree to immediate school-leavers' (S5, 2nd year). Challenge and flexibility were frequently combined, so that a reason to choose the program was 'to experience a greater academic challenge and to have an individually-tailored program – that is, one without any restrictions' (S4, 1st year).

Category 6: Opportunities to develop an understanding of research and acquire research skills

Other students gave reasons for enrolling that anticipate special learning opportunities within the research domain. Students cited 'the higher conceptual learning and the research component' (S14, 1st year) and 'the focus on developing research orientated skills' (S12, 2nd year) as motivations for enrolling in the degree. Some students were motivated by the opportunities to 'gain real research experience in practical projects at a university with an excellent research reputation' (S15, 2nd year). As one student said, regarding whether the program was living up to his expectations, 'I could not have learn[ed] more about real research [in] any other undergraduate degree [that I can] think of. The projects I partook in were often difficult and even frustrating at times, but they were certainly valuable experiences' (S11, 3rd year). Some of these students also anticipated acquiring advanced disciplinary knowledge, which may indicate a belief that preparation for scientific research requires the acquisition of a significant body of content knowledge (a belief shared by many supervising academics [Wilson et al. 2011]).

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The six categories described above form three groups. Categories 1 and 2 share a focus on the exclusivity of the degree, but display a lack of apparent awareness of any special opportunities within the degree itself. Categories 3 and 4 also share a focus on the exclusivity of the degree, but show an awareness of potential benefits through membership of and recognition from a group whose opinions the student values (whether high-achieving peers or academics). Categories 5 and 6 focus on special learning opportunities, either with a focus on conventional coursework or with an awareness of opportunities for new and different learning experiences. Students sometimes gave more than one reason for enrolling in the program, so these categories are not mutually exclusive. Just under one-third of the sample gave reasons limited to categories 1 and 2, in which no special opportunities are envisaged. Two students gave reasons for enrolling limited to peer group and special attention. The remaining students (approximately two-thirds of the students) gave responses which indicated an anticipation of some sort of special learning opportunities, along with reasons associated with categories 1–4. Approximately equal numbers of students were motivated by opportunities for either advanced coursework or research training alone, with six respondents referencing both.

Perhaps surprisingly, there was no evidence of students retrospectively developing more varied reasons for enrolling due to progression through the degree. Some students in the third and fourth years of the program did not cite research experience, acquisition of research-related skills or improved understanding of research as motivations for doing the degree. In contrast, some first-year students suggested a range of motivations including advanced learning, direct experience of research and increased contact with academic staff. A similar level of variation in the sophistication of articulated potential benefits is evident at all stages of the program.

As well as asking students why they chose this program, students were also asked what they thought were the program aims. Answers to this question might be expected to reveal further expectations of what the program might offer and hence how students might benefit from participation. Perhaps unsurprisingly, there were strong connections between perceived aims and reasons given for enrolling. Some students described program aims relating only to recruitment into the university – these students gave reasons for enrolling in the degree that were limited to categories 1 and 2 above. Other students saw the aim of the program as to expose students to research through personal contacts with researchers, reflecting previous findings that opportunities for student–teacher interaction are deemed important (Neumann 1994) – these students tended to give reasons for enrolling that included responses corresponding to category 4 above. Students who saw the program as providing extension work and additional challenge gave reasons for enrolling corresponding to category 5 but not 6. In contrast, those who saw the program as intending to provide preparation for and experience of research gave reasons for enrolling corresponding to category 6 and sometimes also category 5. As with the reasons given for choosing the program, the range of perceived program aims was not dependent on progress through the degree.

Relationship between anticipated and perceived benefits

Although the sample size is limited, the survey responses offer an opportunity to examine some possible relationships between students' expectations of the program (as emerging from their reasons for enrolling and perceptions of the program aims) and the benefits they perceive themselves as accruing. Because some students had not completed any research projects by the time of the survey, their responses cannot be used in this part of the analysis, reducing the sample size to 42 students.

Responses to questions regarding perceived benefits from research projects and contact with academic supervisors confirm the results of previous work examining the experiences of students engaged in undergraduate research projects (Howitt et al. 2010; Hunter, Laursen, and Seymour 2006; Kardash 2000; Laursen et al. 2010; Russell, Hancock, and McCullough 2007; Seymour et al. 2004). Students described gains in a range of areas, from disciplinary content knowledge and technical skills, to written and oral communication skills, confidence, networks of contacts and higher-order research skills. They also reported benefiting from the one-to-one instruction and individual attention from project supervisors. As has been noted in previous studies, however, these gains were not uniform and only a small number of students reported gains in research-related skills and ways of thinking.

Unlike previous studies, our data offer the opportunity to relate anticipated benefits to reported gains. In the following, we focus on anticipated learning opportunities (categories 5 and 6 above), rather than prestige or anticipated special attention (categories 1–4). Our results suggest a fairly strong connection between anticipated learning opportunities and the types of learning benefit students identified themselves as gaining from their research projects, as is shown in Table 1.

Benefits recognised by students who did not anticipate special learning opportunities

Students whose reasons for enrolling in the program were limited to categories 1–4 were equally likely to report either no perceived gains (categories 1–2), gains in

Table 1. Observed relationships between anticipated special opportunities and perceived gains from research experiences.

		Anticipated special learning opportunities		
		Acquire content knowledge only (category 5)	Develop research-related skills and understanding only (category 6)	Acquire content knowledge and develop research-related skills and understanding (categories 5 and 6)
Reported learning gains from research experiences	Content knowledge only	■	–	–
	Research preparation and skills only	–	■	–
	Both content knowledge and research skills	–	■	■

Notes: ■ Filled squares indicate a strong relationship between anticipated opportunities and perceived gains, with a substantial majority reporting this combination of anticipated and perceived gains; – dashes indicate that no student showed that particular combination of anticipated opportunity and perceived gain.

terms of membership of an elite peer group or networking with staff (categories 3–4), advanced learning in coursework (category 5) or research training or preparation (category 6).

Some of these students had difficulty articulating any clear learning gains from their research projects or their contact with academic supervisors. Although one student reported that 'some [projects] were not particularly useful' (S46, 3rd year), students in this group did report some benefits, for example that 'it was good to work and get feedback on a longer time scale' than usual (S10, 3rd year), or '[the projects] saved me from complete boredom' (S37, 2nd year). Benefits from contact with supervisors reported by this group were limited to individual attention, friendship and network-building.

Others in this cohort had encountered unanticipated gains in the form of better understanding, either in limited contexts, 'I have gained a better understanding of the material within [the projects]' (S16, 2nd year), or through increased breadth, 'I think gaining more knowledge in various subjects has been the most beneficial' (S7, 3rd year). Contact with supervisors had brought 'insight into subjects' (S8, 2nd year) and 'someone to supervise and facilitate the extra learning' (S20, 2nd year).

A few students who had not described anticipating any special learning opportunities reported gains in awareness of or understanding of research, describing how the projects 'gave a glimpse of what research life is like' (S8, 2nd year). A small number reported gains in quite sophisticated skills or ways of thinking. For example, student S20, who described enrolling in the degree because of the associated prestige alone, related how 'it has been very enlightening to have my first real taste of science research. It is excellent to know what experiments are really like when they

are not written up for you in a lab manual!' (S20, 2nd year), indicating that the research aspect of the degree had become important to him/her.

Benefits recognised by students who anticipated additional conventional coursework learning opportunities

Those students who had chosen to enrol in the program because they anticipated course flexibility or advanced learning of disciplinary content knowledge (category 5) tended not to identify benefits in the form of skills or research preparation, but instead described learning about more subjects or in more depth. Students were glad to be 'able to choose exactly what to study' (S1, 2nd year), and felt that their projects 'encouraged me to read around the core course material … They have encouraged independent reading' (S19, 3rd year) and 'enabled me to learn in areas I wouldn't otherwise have encountered and cover others at greater depth' (S51, 4th year). Through their projects they had 'been exposed to material not normally in the undergraduate syllabus' (S28, 2nd year), and through their contact with supervisors they had 'been inspired by their knowledge of the subjects' (S19, 3rd year) and had gained 'better knowledge of the material' (S33, 2nd year).

This absence of references to gains in research-related skills or ways of thinking and focus on content knowledge persisted even in the fourth year of the program, suggesting that it may be possible to complete all the research projects required within the first three years of the degree without recognising any increase in research-specific skills or abilities, or at least not to consider such an increase worth reporting.

Benefits recognised by students who anticipated research training

In contrast, those students who were motivated to enrol by the opportunities to engage in, and learn how to carry out, research saw themselves as having gained research-relevant skills and ways of thinking from their projects. Some students described acquiring technical skills combined with improved problem-solving abilities, as illustrated by the following comments:

> The laboratory-based projects gave me experience of what doing research was really like as well as the expertise in the techniques that were often used in the field. (S11, 3rd year)

> [Projects] were good for the experience and knowledge gained of lab techniques and, more generally, approaches to problem-solving when undertaking research. Compared to a standard undergraduate lab, where everything is just set up to work fine, actually working through the many difficulties yourself is better preparation for real research. (S21, 3rd year)

> The projects helped me to develop critical thinking and abilities of trouble shooting and I am more independent in the lab. (S22, 3rd year)

Others emphasised gains in project or experimental design and/or in understanding research culture, as can be seen from the following response:

> I've had experience designing projects and thinking about the question/s a project should be answering. I've learned how much more complicated it is to do anything in an

> organisation than if you did it by yourself (even when you don't have to get funding or anything!) (S39, 2nd year)

Discussion

Prior research on perceived gains has shown that only a small fraction of students report gains in higher-order research skills following research experiences as an undergraduate (Howitt et al. 2010; Hunter, Laursen, and Seymour 2006; Russell, Hancock, and McCullough 2007). It has not been clear whether this is a reflection of genuinely low gains in these areas or a lack of self-awareness of the learning and development that has occurred. Future research using interviews rather than surveys may help to clarify this. The present work suggests that, in some cases, students may be unaware of even the opportunity to gain such skills offered by engaging in research activities. In others, they may be aware of the opportunities, but because this is not what attracted them to the degree, they may not be perceived as gains. In others still, students specifically seek out research-skill development.

The types of benefit experienced by students thus appear to be constrained by their perceptions of what opportunities the degree offers and how they might benefit from these opportunities. Restricting our discussion to those students who do anticipate some form of learning through the research experiences, we suggest that one of the main causes of variation in perceived benefits may be differences in students' conceptions of what it means to do research or develop as a successful researcher (Robertson and Blackler 2006).

Some students may believe that becoming a researcher simply entails acquiring an increased factual knowledge base, rather than developing new skills or ways of thinking. The research preparation aspects of the degree may thus be seen as being fulfilled even by those students who describe gains limited to advanced coursework-based learning. Prior studies of students' understandings of the nature of science and scientific research have revealed a surprising resistance to change. This resistance may indicate that the simple act of participating in research is not in itself sufficient to bring about changes in perceptions of what it means to engage in research or develop as a researcher. For example, Thoermer and Sodian (2002) found little difference in understandings of the nature of science between first-year undergraduate and later-year PhD students. Their results led them to suggest that the considerable restructuring of content knowledge that takes place during undergraduate and postgraduate study is not paralleled by a restructuring of the 'metaconceptual understanding of science' or the development of 'an explicitly articulated metaconceptual notion of interpretative frameworks or theories' (277). Indeed, 'only slight increases in [understanding of the nature of science] were found in comparison with grade 7 students' (277). Thus, although we might hope for increasingly sophisticated understandings of the nature and practice of science and scientific research through exposure to and immersion in research work, that even the PhD experience does not always appear to result in such improved understandings suggests that it is even less likely when the research experiences constitute disconnected, assessed projects that are carried out within the undergraduate degree framework.

In a study of the effects of science internships (which may be thought of as closely paralleling undergraduate research experiences) on participants' understanding of the nature of science, Schwartz, Lederman, and Crawford (2004) found a range of advancements, from no change to a significant increase in nuance and sophistication. However,

their results indicated that 'the research experience, if considered by itself, had little impact on interns' conceptions of [the nature of science] … [lending] support to the claim that just "doing science" or experiencing scientific inquiry in an authentic setting is *insufficient* to change or enhance students' understanding' (633). Of particular relevance to the present work, their study showed that students who were confident in their initial views were unlikely to change because 'they saw no need for change' (633). The cohort in the present study, who have excelled at all prior levels of education, are likely to have had their perceptions of what it means to learn and do science repeatedly reinforced by their previous success. This may make it harder for such students to realise that other types of learning may be desirable or even possible.

Even in an eight-month final-year research project, a significant improvement in the understanding of the nature and practice of science occurred in only a few students (Ryder, Leach, and Driver 1999). Thus, it seems that exposure to science content or to research does not necessarily result in a greater understanding of the processes of science and the nature of research. This in turn may limit the benefits that students recognise from their research experiences. If students enter the degree thinking of scientific research as the incremental acquisition of new content knowledge through study processes with which they are already familiar, this could constrain the possibilities for learning in the research-rich PhB degree in at least three ways.

First, the high degree of flexibility of the program enables students to focus on certain aspects at the cost of others, so that in some cases students may avoid authentic research experiences and the development of research-related skills because they are focused on gaining more content knowledge as the best form of research preparation. This avoidance may be facilitated by the attitudes of supervising academics, some of whom also focus on the transmission of advanced content knowledge as the purpose of undergraduate research experiences (Wilson et al. 2011), and hence provide projects that are more like reading courses.

Second, students' prior expectations may mean that, even if they do not avoid authentic research experiences, they are less likely to notice the special opportunities for development of critical thinking skills and conceptual change offered by these experiences, and so are less likely to benefit from them.

Finally, it may be that students only or more frequently report gains that they value highly, and so, although they may be exposed to all aspects of the degree and indeed even gain some new skills and understandings, they only report a subset of these gains as *benefits*. Such a pattern of under-reporting or devaluing has been observed in a recent study of high school students engaged in science internships (Hsu, Van Eijck, and Roth, 2010). In that study, it was found that 'even though students had experienced the aspects of community and division of labour, they still devalued or even ignored their importance' as core elements of scientific research practice (1262).

Thus, our results add to a pattern already being established, suggesting that the potential impact of early undergraduate research experiences on students' learning is constrained by students' understandings of what research is and their awareness of opportunities for different types of learning. Work with school students has suggested that explicit, guided reflections are powerful tools to increase the sophistication of their understandings of the nature of science (Schwartz, Lederman, and Crawford 2004). We suggest that a similar approach, focusing on the nature and processes of research, could be an important component of undergraduate research experiences. Inclusion of such guided reflections within research experiences may enhance their effectiveness in increasing students' understandings of research and development of generic skills.

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