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'Please remember we are not all brilliant': undergraduates' experiences of an elite, research-intensive degree at a research-intensive university

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Undergraduate research experiences are being incorporated into degree programs with increasing frequency. However, there has been little study into their effectiveness in preparing students for research or into the learning gains that students realise from one or more research experiences. We surveyed science students in an elite, research-based undergraduate degree program at a research-intensive university. These students complete six research projects during their degree and we aimed to delineate factors that students perceive as leading to either good or bad experiences. Two factors stand out as contributing to a successful research experience: the supervisor, with students reporting both pedagogic and affective benefits of good supervision; and the feeling that they are doing authentic science. Surprisingly, given the research-intensive nature of this degree, the learning gains students report relate to both an appreciation of what research is like and life skills, such as time management, rather than scientific thinking skills.

Keywords: generic skills; learning outcomes; research-led education; research skills; undergraduate research experience

Introduction

Background

The Boyer Commission Report (1998) proposed that research experience should be an essential and distinctive part of undergraduate programs at research-intensive universities. Since then, undergraduate research experiences (UREs) have been integrated into an increasing number of degree programs, and not just at research-intensive universities (Hu, Kuh, & Gaston Gayles, 2007; Krause et al., 2008). The inclusion of research in undergraduate programs has also become an important component of rationales about the nature of higher education and university quality (Brew, 2003). The provision of UREs where undergraduates interact with high profile researchers is seen as a distinguishing feature of the education provided by research-intensive universities. Undergraduate research experiences have been adopted more widely because of the importance of undergraduate research training in ensuring a supply of

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future researchers and the desire of less research-intensive universities to maintain their status as research-active. Although the number of institutions offering UREs is thus increasing, serious consideration of what makes UREs valuable to students, and what elements must be included in their implementation to ensure high quality and equity standards, has barely started.

Proponents of UREs claim that they enhance students' critical thinking and problem-solving skills and better prepare them for future research, whether in academic contexts or as lifelong learners. Yet the evidence on which such claims are based (reviewed by Seymour, Hunter, Laursen, & DeAntoni, 2004) is at best anecdotal and at worst absent. The majority of students are positive about their research experiences but rarely report gaining higher-order research skills such as identifying research questions and formulating hypotheses (Hunter, Laursen, & Seymour, 2006; Kardash, 2000; Lopatto, 2004; Russell, Hancock, & McCullough, 2007; Seymour et al., 2004). A rigorous evaluation of summer students at four liberal arts colleges found that the major benefits to students, reported by both students and staff, related to an awareness of research and professional socialization (Hunter et al., 2006; Seymour et al., 2004). Although benefits were categorised as 'thinking and working like a scientist' and 'becoming a scientist', few students developed an awareness of the provisional nature of scientific knowledge and an understanding of how to formulate research questions.

Our interest arose from the introduction of an elite, research-based science degree program, the Bachelor of Philosophy or PhB (Science), at a research-intensive Australian university (Newitt, 2007). Students in this program undertake UREs that are assessed and contribute 25% to their degree, providing a different context to UREs in previous studies (typically summer scholarship programs). When a URE is taken as an unassessed vacation experience, it may not be perceived by the student as an educational experience *per se*. Students may simply not recognise that they are learning how to do science through the URE and this may be a significant factor contributing to the low profile of scientific learning gains identified following such experiences. Indeed, two studies reported that perceptions of the benefits to students differed between students and supervisors (Hunter et al., 2006; Lopatto, 2003), with supervisors more frequently (although still rarely) identifying gains in higher order thinking skills. In contrast, when UREs are included in the curriculum as significant assessment components, students may expect, and therefore be more likely to recognize and articulate, concrete learning outcomes.

It is also possible that a single research experience is simply not enough to allow the development of a deeper understanding of how science is done. Because students enrolled in the PhB undertake multiple UREs, this program provides a unique opportunity to compare student research experiences and examine the potential benefits arising from repeated research exposure. Identification of both perceived and actual learning outcomes under such circumstances is therefore of great interest.

Previous studies have suggested that supervision is a critical aspect of UREs. In a survey of almost 15,000 students at a range of institutions, the most frequent response to an open-ended question on what would have improved their research experience related to improving supervision (Russell et al., 2007). Following their study of summer research experiences at liberal arts colleges in the USA, Hunter and others concluded that a cognitive apprenticeship model was a good description of the way in which student learning occurs during UREs (Hunter et al., 2006; Seymour et al., 2004). These findings imply that quality of supervision is a significant determinant of the effectiveness of student learning. It has been suggested both that quality of

supervision may be more uneven at research-intensive universities (Hunter et al., 2006) and that students may value effective supervision above the availability of state-of-the-art facilities (Lopatto, 2003). It has also been observed that training of supervisors improves students' experiences (Pfund et al., 2006). Worryingly, two studies found a mismatch between supervisor and student expectations for UREs (Lopatto, 2003; Stefani, Tariq, Heylings, & Butcher, 1997).

Where UREs are included as assessed components of the curriculum, supervision is likely to become even more critical, as it influences both affective and pedagogical outcomes. Potentially problematic areas include: training for supervisors; identification of the educational aims of UREs; equity issues such as non-uniformity in mentoring and pedagogical quality in UREs; and evidence-based understanding about what constitute good and bad research experiences. This study addresses these issues by delineating factors that students undertaking multiple UREs in an elite research-based degree program at a research-intensive university perceive as contributing to their best or worst research experience and by further probing the influence of the supervisor.

The PhB (Science): context of UREs in this study

The PhB degree was introduced by the Australian National University (ANU) in 2003 and has been described in detail elsewhere (Newitt, 2007). It is open only to the top 1% of school leavers and requires students to maintain a high GPA. The degree aims to provide research experiences for elite students. The first three years of the PhB degree include six Advanced Studies Courses (ASCs), ostensibly research-focused experiences, which are chosen by the student with advice from a mentor. These may be undertaken in any discipline and, while most students specialise relatively early (the majority in maths and physics), some choose projects from a wide range of areas, including outside science. The broad aim is that the ASCs should provide substantial research training and experience and hence the intention is that they should take the form of 'genuine' research projects conducted under the supervision of an expert researcher. Advanced Studies Courses may take place in either 'stand-alone' mode (replacing a full semester lecture course) or 'add-on' mode (extending a standard course and typically accounting for 20–30% of the associated assessment). At least three ASCs must be in stand-alone mode and are comparable to UREs in summer research programs. These projects may be supervised by research-only staff who do not normally contribute to the undergraduate curriculum. In the science schools at the ANU, research-only staff outnumber teaching and research staff by 4:1 and may be in separate departments, providing a potentially significant pool of projects in a research-intensive environment.

The context of UREs in the PhB degree is thus quite different from earlier studies. They take place in a research-intensive university where many staff have research-only positions with no other contact with undergraduate students; they are both undertaken for credit and formally assessed, contributing to the student's GPA; at least half of the UREs replace significant elements of the standard science degree curriculum; and students do multiple research projects with different supervisors.

Methods

For this study, a survey approach was considered appropriate, given the number of students and the diversity of the cohort in both year level and discipline area. We

wished to obtain information about the range of student experiences across the program. The design of the surveys was informed by data from initial surveys of incoming and continuing students and anecdotal information (Wilson, Howitt, & Wilson, 2007). Surveys were administered online and focused on students' perceptions of features that had contributed to either good or bad research experiences. Students were told that the purpose of the survey was to gain information about their experiences of ASCs. The survey was offered in the second half of the academic year and was open for a period of six weeks to all students enrolled in the PhB (Science) program at second year and above. First-year students were excluded to ensure that all respondents had completed at least one ASC.

Students were asked to rate statements on a scale of 1–5 (from strongly agree to strongly disagree) and were also asked open-ended questions relating to their experiences of ASCs. We have taken a frequency-based approach to identify emergent themes from open-ended questions. Responses were independently coded by two of the authors. Individual categories were compared and a set of agreed response categories generated for each question. Responses and categories were reviewed iteratively until a stable analysis was reached. If a respondent offered several different answers to a single question, all have been included in our identification of themes, since we are interested in the range of perceptions and experiences of participants in the PhB, not in categorising particular responses.

Results

Survey respondents

Of the 89 students eligible, 55 completed the survey, a response rate of 62%. A total of 283 ASCs had been undertaken, with all students having completed at least one stand-alone and one add-on project. The characteristics of these students and the type and number of ASCs completed (Table 1) indicates a representative sample of PhB students, averaging five ASCs per student, consistent with the year profile of the respondents (Newitt 2007). The 13 honours (fourth-year) students who completed the survey had completed all six ASCs required for the PhB program. In the honours year, students complete, and are assessed on, a significant research project.

We use the terms supervisor or instructor to refer to the person who supervises student research projects. PhB students also have a mentor, who oversees their program but is distinct from their research project supervisors.

Table 1. Characteristics of students and projects.

Category		Percentage students (n = 55)	
Year	43 second	33 third	24 fourth (honours)
Sex	60 male	40 female	
Category		Percentage projects (n = 283)	
ASC mode	57 stand-alone	43 add-on	
ASC area	41 lab-based	34 theoretical/ computational	25 literature reviews

'Interesting material and lots of guidance' or 'way above my level and too little time': what makes a good (or bad) research experience?

As Figure 1 illustrates, students were generally positive about their experiences. Advanced Studies Courses were seen as both more challenging and more enjoyable than standard coursework by the majority of students, although there were dissenting minorities, with 20% preferring coursework. The responses also indicated room for improvement, particularly in terms of structured learning or skills development. Although 78% of students felt they understood the purpose of the assessment items used to evaluate their performance in ASCs, only 58% felt they knew what was expected of them from the start of a project, 25% felt they did not have time to

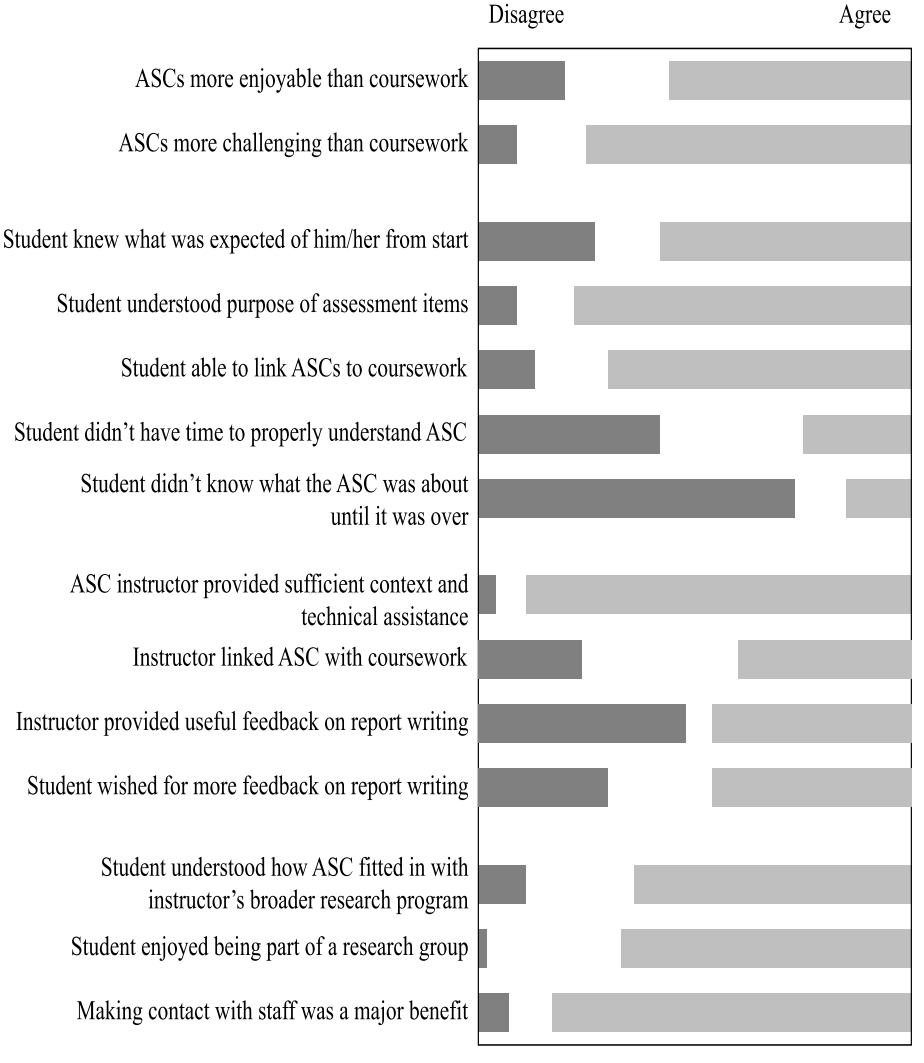

Figure 1. Students' enjoyment and understanding of research experiences.
Note: The proportion of students disagreeing or strongly disagreeing with each statement is indicated by dark grey bars on the left while the proportion agreeing or strongly agreeing is indicated by light grey bars on the right. The unshaded area between the bars indicates the proportion that neither agrees nor disagrees.

properly understand their project and 15% felt they didn't understand the project until it was over.

When asked to rate statements about the performance of their supervisors, the students were again positive, with 89% indicating that supervisors provided a sufficient level of background information and technical assistance. However, only 40% felt that their ASC supervisors provided them with useful feedback when it came to writing the (assessed) report and a similarly low fraction agreed with the statement that supervisors linked extension material to coursework. Supervisors were somewhat better at linking the student's project to their own group's wider research and students enjoyed being part of a research group. The majority (83%) of students felt that the opportunity to interact with staff was a strong positive of the program.

These results, while interesting, reflect the students' *average* experiences across multiple ASCs. Of respondents, 57% had completed three or more stand-alone projects and we might expect to find significant variation in student experience from project to project. To probe more deeply the characteristics that lead undergraduates to identify research experiences as successful, we asked the following open-ended question: 'Think about your best ASC. What made it the best?' Two clear themes emerged from the responses: enjoyment of the process of research and the role of the supervisor (Table 2). Within each theme, different levels of sophistication were evident in the responses.

On enjoyment of research, 20 students described a specific ASC as the best simply because they had enjoyed lab work or found the project interesting or 'cutting edge'. Students also valued the perception of 'doing real research', which included getting results (13 responses) and feeling like they were making a real contribution or becoming a valued member of a team (9 responses), as illustrated by responses such as:

> Feeling that I was really contributing to furthering the group's research and not just learning from them.

> Individually contributing to a known research problem was an amazing experience. I'd say what made the ASC the best was applying the theory I'd learnt in standard courses to a known problem and getting a result.

> It was great because I was able to do new work, got a buzz out of seeing something for the first time.

A few students cited opportunities for personal development, such as being able to work independently and having the opportunity to learn from mistakes, as key features of their best ASCs (Table 2). Such skills are widely seen as crucial to the successful scientific researcher and hence contribute to the feeling of participating in real research or in a real research process.

The second major factor contributing to students choosing a particular ASC as the best was the supervisor, with quality of supervision mentioned in 22 responses. Comments ranged from non-specific (supervisor was 'nice') to detailed reasons for the effectiveness of supervision. Students highlighted both affective and pedagogic factors in describing the supervisors of their best UREs: students described supervisors in terms of their approachability and enthusiasm and described feeling 'a priority' and 'trusted' but also praised supervisors for being organized and thorough, for providing appropriate guidance and feedback and for their expert knowledge. Comments included:

Table 2. Factors contributing to student's best research experience.

Category of response	Number of responses
Enjoyment of research process	
Doing interesting/challenging research	20
Getting good/interesting/new results	13
Being part of a team/contributing	9
Learned skills	2
Working independently	2
Opportunity to learn from mistakes	1
Total	47
Good supervision	
Good/great/nice supervisor	9
Support from supervisor	6
Enthusiastic supervisor	5
Expert supervision	2
Total	22
Good project	
Well designed	6
Applying theory	4
Total	10

> … an organised, enthusiastic supervisor who gave me lots of feedback on how I was doing.

> My supervisor was amazing. He was very tough on me but the tasks he set were all achievable. The research and report I produced were easily the best pieces of work I've produced at university and it was largely because of him.

These findings are consistent with previous work highlighting supervisors' multiple roles (Lopatto, 2003).

To further clarify the characteristics of ASCs perceived as good by the students, we asked for similar comments on their worst research experiences. The responses clearly showed that the major factor was the quality of supervision (Table 3), with 25 students directly mentioning supervision and a further 20 being dissatisfied with their project (which is designed by the supervisor, although students may have input). Two related supervisory issues emerged: failure of the supervisor to provide adequate guidance (14 responses) and a mismatch between supervisors' expectations and goals with those of the student (11 responses). Responses on the first issue included:

> Supervisor was never around and didn't really know what to do!

> … poor guidance and little feedback from instructor.

> I had no idea how to operate the program and had to repeatedly seek out my instructor so that he could show me how to do the most basic commands. He did not explain how to use the program very well and my lack of progress led to a lack of interest.

The second, related problem pertained to performance expectations and appropriateness or clarity of project goals. One of the benefits of running such a program at a

Table 3. Factors contributing to student's worst research experience.

Category of response	Number of responses
Poor supervision	
Not enough help/guidance	14
Expectations too high or unclear	11
Total	25
Project	
No results/boring work	10
No defined project	5
Project involved no more than text book reading/problems	5
Total	20
Personal	
Not enough time/poor time management	11
Doing it because I had to have an ASC	2
Not understanding	2
Total	15

research-intensive institution is the large pool of active researchers from which supervisors can be drawn. However, such staff generally have little or no contact with undergraduate students so may know little about what is in the undergraduate curriculum or about the prior knowledge and skills development of their students. They do know that their students are in the top 1% academically, which can lead to unreasonably high expectations of abilities and understanding. Such circumstances contribute significantly to students' perceptions of their worst ASCs, as the following responses illustrate:

> Being unsure of the goals of the ASC.

> Not being able to understand the theory I was asked to comprehend and feeling stupid because I couldn't make myself understand.

> Too high expectations from instructors that sometimes I feel like I didn't get enough help.

> Not only was it difficult to get the actual experiment working, understanding the background material was, really, beyond me. My supervisor seemed quite frustrated and disappointed in me as a result of this which was a bit soul destroying.

Some worst ASCs were the result of boring work or failure to get results (10 responses). While both of these are features of all scientific work, it is essential that students be able to identify learning gains from such experiences. Students suggested that projects should be designed to be both interesting and achievable within the required one-semester time frame. Thus, a reason for identifying an ASC as the best was:

> The satisfaction of seeing a long project through from start to finish.

while reasons for the worst ASC included:

> Being an extra lab hand in miscellaneous work rather than a clear project with achievable goals.

> No or little progress during the project.
>
> Not knowing what was going on most of the time in the lab – I just slotted in once a week and missed things.

Some students attributed their worst ASC experiences to their own inadequacies (15 responses) mostly related to time management, as illustrated by the following:

> I wasn't really interested and left it to the last minute.
>
> I don't have time to spend long enough on it to really get much out of it.
>
> It was the worst because I got stuck early on and ended up doing the majority of the work in the last month of semester (including exam period). It was very stressful to have to make up so much ground in the middle of studying for exams. As to why I got stuck it was partly due to procrastination and partly due to major difficulties getting started.

For at least some, this was a learning experience as they recognised that they needed to change their behaviour to get the most out of the PhB program. These answers may, however, mask supervisory problems, as students' feelings of inadequacy are in some cases related to the inappropriate expectations of supervisors described above. In addition, since a significant part of the supervisor's role is to mentor the student through the research experience, our results suggest that motivation and encouragement are key activities, which may not always be adequately performed.

'How science really happens outside the classroom': perceived learning gains and research training

As mentioned above, previous studies have shown that students rarely report gaining higher-order thinking skills from single UREs (Hunter et al., 2006; Kardash, 2000; Seymour et al., 2004). Students gain skills in group work and familiarity with some aspects of cutting edge research, but may still lack the practical and context knowledge and critical and integrating thinking skills required for activities such as identifying research questions, developing hypotheses and designing means of testing hypotheses. We were particularly interested in these aspects as one stated aim of the PhB program is to produce 'research-ready' graduates. While professional socialisation is clearly an important part of this, the experience of multiple research projects may promote the development of those scientific learning outcomes missing from single UREs.

We therefore explicitly asked students to identify the most important things learned through their ASCs. Perhaps surprisingly, the responses to this question confirm conclusions of earlier studies but do not raise any significant new areas of perceived conceptual, technical or personal development, despite the different context for UREs in our study and the intensity and duration of the program. Only four students mentioned higher order thinking skills and these were related to specific contexts, e.g. 'the ability to critically analyse and interpret scientific papers'. A more common theme (40 responses) related to the nature of research or research practice (Table 4). Students described learning about the difference between a lab-based research project and a formal undergraduate laboratory, the diversity of research, how scientists work and the need for repetition and hard work. Three had discovered that

Table 4. The most important things learned from ASCs.

Category of response	Number of responses
About research	
What research is like	15
How to do research/methods	11
Diversity of research	4
Hard work/need for repetition	4
Fun/enjoyment of research	3
Differences from undergraduate labs	3
Life as a researcher	2
Experiments don't always work	1
Total	40
Personal	
Time management organisation/need for goals	11
Talking to academics, making connections	3
Independence	2
Confidence	1
What type of research I like	1
Can't learn everything	1
Total	22
Skills	
Communication/report writing	6
Critical thinking/analysis/ problem solving	4
Lab skills	3
Content knowledge, linking theory to practical	3
Keeping a log book	1
Total	17

research was fun, with one student 'finding out how much fun it is to work on a big problem that might take several months to solve.' Seventeen students referenced gains in generic skills including writing, analysis of papers, time management and organisation, problem solving and independence.

Many students had made personal discoveries about their need to develop what might be termed generic life skills, which are useful in supporting further learning or research, in particular relating to greater organisation or time management. For example one student found, 'That I have to really make myself keep going when I get stuck on something and that I have to allocate time every week towards my ASC.' PhB students have greater responsibility for their degree program than other students, having control over choice of courses and ASC instructors. This aspect of the degree may bring them face-to-face with the importance of self-motivation and planning earlier, and in a more urgent way, than is the case for their BSc peers. Indeed, one student's worst experience was 'Not knowing how to organize an ASC.' However, some students do not take full advantage of the support available to them, with only about one third of the students discussing possible ASCs with discipline coordinators or using the PhB web site as a source of information about projects. Lecturers were more frequently turned to for advice, with around 75% of students saying they talked

to their lecturers when looking for a project. Thus students may learn that they need to plan their time and activities, but they do not always do so using the support and information available to them.

A series of agree/disagree statements was used to test students' understanding of and readiness for research (Figure 2). A clear majority agreed with the statement that their ASCs had taught them 'a lot about how research is done', with only 15% disagreeing. Similarly positive responses to statements relating to improvements in students' understanding of how scientists address problems and on the breadth of research types accessed through ASCs, suggest that the PhB is at least achieving its goal of creating a research-focused undergraduate degree. Most students also gained confidence in their research abilities, although only about 50% felt part of a community of researchers.

It is perhaps the students at Honours level, who have completed the ASC requirements of the PhB program and gone on to undertake a more substantial research project, who can provide the most information on how they perceive their progress in developing into a research scientist. We therefore asked students at this level whether they felt ready for research as a result of their experiences in the PhB program. Responses were mixed, with eight students saying yes, four saying partly or maybe and one saying no. Students generally felt that the experience of research had helped them know what to expect in the honours year. However, three students had learned that they did not want a research career and as these quotes show, this was directly linked to their research experiences:

> Yes, but it's been overkill and research is the last thing I want to do next year.

> … after seeing the kind of life an academic researcher has (scarce funding from the school, stressful grant application, experiments normally don't work, papers may take years to be published and being underpaid), I'm not sure I'd want to stay in research.

Some students at this level felt their ASCs had furnished them with an advantage over standard science degree students in generic skills (writing, organisation and, in

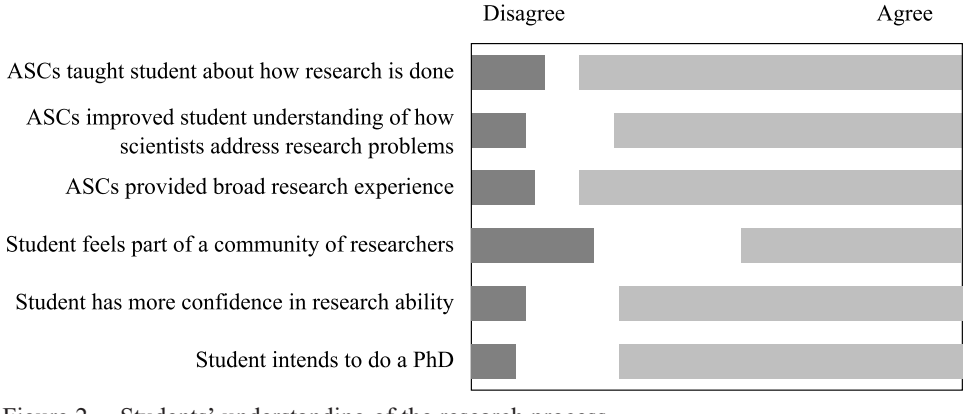

Figure 2. Students' understanding of the research process.
Note: The proportion of students disagreeing or strongly disagreeing with each statement is indicated by dark grey bars on the left while the proportion agreeing or strongly agreeing is indicated by light grey bars on the right. The unshaded area between the bars indicates the proportion that neither agrees nor disagrees.

one case, experimental design). Others did feel prepared for research, but not just because of their ASCs, and one student even reported that course work had been better preparation than ASCs. Typical responses included the following comments:

> Feel a little more confident but not completely ready.

> I still feel I don't know enough to do things on my own, I still am unsure about what goals are achievable and what isn't.

However, some students were very confident in their own abilities, as shown by:

> Yes, though I've already done published work in my ASCs so I don't feel research is something I'm going to start doing. It's something I'm already doing.

Overall, it does appear that multiple ASCs provide useful preparation for research in terms of familiarising students with the research environment and in giving them practice in the types of assessment required for honours level research.

'You don't want to fall behind in your ASC quota': curriculum issues

Some students highlighted perceived problems with the inclusion of several ASCs in the standard curriculum and the concomitant loss of other curriculum elements. One concern was that foundational material, or breadth in terms of the content knowledge and technical skills acquired in normal coursework, was being sacrificed. In open-ended questions, very few students referenced better understanding of content arising from their ASCs. Indeed, 35% of students agreed that they had missed out on courses they had wanted to do in order to fit in six ACSs, and although 35% of students agreed with the statement, 'I learned more about my subject area from my ASCs than my standard courses', 25% disagreed.

Opinions on the value of add-ons were also divided, with 47% agreeing they were useful extensions to normal courses and 29% disagreeing. This type of ASC was mentioned by several students as being their worst, with the most frequent concerns arising from too much work being expected (since the normal course is still done in parallel) or with the add-on material having little relationship to the rest of the course. The following comments illustrate the time pressure that can result:

> My first ASC was an add-on for which the amount of work was unreasonable – it could easily have been a stand-alone.

> I was doing an add-on to a course and the material I needed for the project wasn't covered until halfway through the semester. I suppose I could have taught myself the material, but in that case why do the course.

The issue of having time to understand and complete a research project in a single semester is of concern to students and justifies further attention. These students do three standard courses at the same time as each research project and are also required to maintain an average mark of 80% each semester. Often, the assessment for the ASC is not due until the end of semester, which can lead to a conflict between report preparation and revision. Equally problematically, standard coursework assessment items must be submitted almost every week and students often find it hard to prioritise

project work, or conversely, may find that a particularly exciting or demanding part of the project causes coursework grades to suffer. Not surprisingly, 60% of the students agreed that the PhB program was stressful.

'Force your instructor to lay out clear goals': advice to students

As a further means of identifying both what the students had learned through their research experiences and what they thought they needed to do to create a good research experience, we asked what advice they would give to a new PhB student. The advice offered was quite varied (Table 5) but much of it focused on either organizational skills or affective aspects of research experiences.

Forty-three students provided suggestions for choosing ASCs, with supervisors again featuring frequently. Ten responses advised choosing a project on the basis of the instructor, as shown by, 'Find a friendly and interested instructor. Generally, the nicer the instructor, the better the ASC experience', while seven advised talking to different instructors before committing to a project. Students are clearly aware that one advantage of the program is the opportunity to experience different research areas as many also advised trying different types of projects.

Another common theme related to the students' own approaches to ASCs and program organization, planning and management (34 responses), with a further 6 advising on management of the ASC. New students were advised:

> Map out a wish list of courses until third year so you can see when you will have the expertise to do an ASC.
>
> Make sure you stay on track and monitor your progress carefully.
>
> Don't be too ambitious with your projects. Take the time to really learn and absorb the material.
>
> Takes a lot of work but usually results in something you are proud of.

Five responses advised students to assist their supervisor with setting goals, as epitomised by the following response: 'Force your instructor to lay out clear goals and what their expectations are.'

Only two answers referred to the importance of considering assessment options, which is perhaps surprising as assessment is agreed upon by the student and supervisor at the beginning of each project. However, there is little variation in assessment, which typically includes a research report, a seminar and lab book, so students may take this for granted.

These responses are consistent with students' perceived learning gains, reinforcing the conclusion that PhB students undertaking multiple ASCs gain more in self-direction, organizational and time-management skills than in research-specific or 'scientific' skills.

'Don't assume that PhB students know everything!': advice to supervisors

We also asked students what advice they would give to a new ASC supervisor. The majority of responses to this question reinforced the conclusions drawn above relating to the role of the supervisor, with the most frequent response (20 students) advising supervisors to spend time with their student (Table 6). Thirteen responses suggested

Table 5. Advice to a new student.

Category of response	Number of responses
Choosing ASCs	
Try different things	15
Choose a good supervisor	10
Talk to many potential supervisors/other students	10
Choose projects that interest you	8
Total	43
Be organized	
In planning your six ASCs	12
Find out about ASCs/instructors before deciding on an ASC	12
For each ASC	7
Maintain balance between amount of work done for ASCs and other courses	3
Total	34
Managing an ASC	
Ask supervisor for clear goals	3
Think about assessment	2
Be a good listener	1
Total	6

supervisors make themselves familiar with the level of the student, what courses they had done or what they could be expected to know. Supervisors should also be helpful, caring and interested (7 responses). Project design was important, with 16 respondents advised supervisors to set clear goals and make their expectations clear; 7 mentioned the need for progress to be monitored and feedback provided and a further 6 wanted the project to be achievable, interesting or at the right level. The nature of the responses made it clear that students felt strongly on these issues:

> They're an undergraduate student not an honours/PhD/postdoc! And keep in mind the limited time when assigning a project. It should have an achievable goal.

> The best instructors are those who have time to talk to the students, and are available to do so.

> First, please read the guide for instructor, second please understand we are not all brilliant. We are hard working and it is hard to understand 30 years of your work in 1 ASC.

> Set small, incremental targets for your PhB student. Let the student know what is expected of her/him during the project and provide constant feedback.

Conclusion

In summary, we surveyed 55 students in the later stages of an intensively research-focussed undergraduate degree to investigate what factors they perceive as leading to good research experiences and to identify the major perceived learning gains derived from undertaking multiple UREs.

Our results confirm those of earlier studies that examined single UREs in demonstrating that the quality of supervision, both in its mentoring and pedagogical aspects,

Table 6. Advice to a new ASC supervisor.

Category of response	Number of responses
Interaction with student	
Spend time with the student	20
Be familiar with level/knowledge of student	13
Be interested/caring/helpful	7
Monitor progress and provide feedback	7
Total	47
Project design	
Clear goals and expectations	16
Interesting/ at right level	7
Total	23
Be familiar with PhB program	3

is the most important factor in providing good research experiences. Not only was poor supervision the most frequently mentioned cause of students' worst ASC, good supervision was the second most frequent reason given for the best ASC. However, our findings differ from earlier studies in the learning gains reported by students: we found that the organisation and management of multiple ASCs is as important a factor as actually participating in research. Much of the advice offered to new students related to choosing an instructor, preparing the instructor or preparing themselves to work with little supervision. Many students report improved time management and organization skills or at least recognition that these skills are important. It appears that a major learning gain from this multi-URE program arises from the responsibility that students have to identify supervisors and projects and to manage URE workload against normal courses, rather than from their participation in scientific research. While most students report learning what research is like in general terms, few reference learning gains in their discipline areas or in higher-order research-related skills such as critical thinking, identifying research problems and formulation and testing of hypotheses. While similar results have been found in other studies (Hunter et al., 2006; Kardash, 2000; Seymour et al., 2004), it might have been expected that a research-intensive degree program would result in more development in these areas than a single URE. It is possible that students do not recognise that they have developed skills in scientific thinking; other methods to evaluate their development in this area are needed to complement student surveys.

Most students were very positive about their ASCs. Many also valued the experience of being part of a research group and found that personal interactions with academic staff were a major benefit. It is clear that the nature of the project itself is very important. Projects need to have a structure, with a goal that can be achieved in a single-semester time frame. Students' best experiences arise when they feel they are engaged in authentic research, but not when that research is in the form of dull, repetitive work or when nothing positive is achieved.

Our results indicate that many supervisors need to give greater consideration to both the pedagogic aspects of project design and their role in mentoring the student. The most frequent advice to supervisors was simply to spend time with their student. This accords with Lopatto's (2003) view that effective staff/student interactions are important in producing positive outcomes from UREs. Consideration of this factor may be critical in programs where research-only staff supervise UREs. Supervisor

training in one URE program resulted in student and supervisor expectations becoming more closely aligned, leading to greater student satisfaction (Pfund et al., 2006). Our findings strongly support this strategy; as one of our students advised, 'Choose an instructor who's supportive and will be there for you, don't choose an instructor based on fame.'

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