# Matching the background of demonstrators with those of their students: does it make a difference?

Final report 2016

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# List of acronyms used

| | |
|---|---|
| ACDS | Australian Council of Deans of Science |
| EJP | European Journal of Physics |
| FNDPEAU | Forging New Directions in Physics Education in Australian Universities |
| HOD | Head of Department |
| HREC | Human Research Ethics Committee |
| IJISME | International Journal of Innovation in Science and Mathematics Education |
| IOL | Inquiry-Oriented Learning |
| OLT | Office for Learning and Teaching |
| PAN | Physical Aspects of Nature |
| PQU | Planning and Quality Unit |
| SFS | Student feedback surveys |
| SMaPS | School of Mathematical and Physical Sciences |
| SPAM | School of Physics and Advanced Materials |
| STARS | Student Transitions Achievement Retention and Success |
| UCT | University of Cape Town |
| UQ | University of Queensland |
| UTS | University of Technology Sydney |

In this report we make reference to subjects which are taught components of one semester duration. In other institutions such subjects might be referred to as courses, modules, or units of study.

Executive summary

## Project Context

Well-conceived and well-delivered undergraduate science laboratory programs encourage students to develop and enhance their inquiry, experimental and communication skills and urge deeper insights into scientific principles. The laboratory is a setting in which authentic scientific inquiry can occur (Hume and Coll, 2008).

Despite the promise of the laboratory as an inspiring and effective learning environment, concern has been expressed over many years as to what the undergraduate science laboratory delivers of benefit to students (Hegarty, 1978). There is regular criticism, expressed by students, of their experiences of the undergraduate physics laboratories (Kirkup, 2015). This is particularly true of students for whom physics is a service subject (Kirkup, Johnson, Hazel, Cheary, Green, Swift, and Holliday, 1998). The reasons for widespread student dissatisfaction with the first year physics laboratory experience remain unclear. However, there is little doubt that the demonstrator plays a pivotal role in creating and maintaining a positive and productive learning environment especially in those situations in which student-centred learning is promoted. Rice, Thomas and O'Toole (2009) found that for many students, "*demonstrators had the power to make a lab a great or a miserable experience"* and called for a project to be undertaken to "*promote change in the system of laboratory demonstrating*". This Seed project is an answer to that call.



## Aim of project

By examining student and demonstrator experiences and perceptions of the undergraduate physics laboratory we wished to enhance the value to students of undergraduate physics laboratories. More specifically, our aims were to:

- examine the influence of alignment between the background, ambitions, and views on teaching and learning of students and their demonstrators on student engagement and satisfaction.
- explore students' and demonstrators' views about learning and teaching in the physics laboratory and how these views manifest themselves in student-demonstrator interactions.
- investigate aspects of student-demonstrator interactions students consider helpful in increasing their engagement with laboratory work.

As an outcome of this work, we intend to advise on demonstrators' recruitment, induction and professional development as well as offer commentary on issues impacting on student experiences in the undergraduate laboratory.

## Project approach

Stimulated by work begun at the University of Cape Town, this project adopted several approaches to exploring and examining student and demonstrator experiences and perceptions of an undergraduate physics laboratory for a large-enrolment first-year physics service subject at UTS. These approaches included, but were not limited to:

- centrally administered student feedback surveys gathered longitudinally over several years.
- paper-based surveys of students and demonstrators comprising closed and open-items to probe student and demonstrator experiences and expectations of the laboratory.
- semi-structured interviews of students and demonstrators (at UTS) as well as students, demonstrators, subject convenors and the head of department (at UCT) in order to validate the data from the surveys and to grasp the opportunity to examine more directly stakeholders' values, beliefs, concerns, experiences and attitudes towards laboratory work.
- Observations carried out in undergraduate laboratories using a 'fly on the wall' approach. An unobtrusive video camera was used to capture events, activities and incidents that may have been raised or commented upon during the semi-structured interviews.

We took the opportunity to engage in action research at UTS in response to student and demonstrator experiences as evaluated through the surveys and interviews. Upon completion of an intervention stimulated by findings from spring 2014 surveys and interviews at, we surveyed students in autumn 2015 semester and compared student perceptions with those expressed in spring 2014.

## Project outputs and deliverables

Project outputs include: student and demonstrator survey designs adaptable to other contexts and disciplines which support the exploration of student and demonstrator perceptions, expectations and experiences of laboratories, and; semi-structured interview questions allowing for more detailed examination of student and demonstrators beliefs about laboratories and their mutual interaction. These resources, along with details of the project aim, methodology, findings and details of dissemination, can be found at http://www.iolinscience.com.au/demonstrators-students/participants-method/

### Presentations and workshop:

STARS conference presentations, Melbourne, 3rd July, 2015, *Matching the background of demonstrators with those of their students: does it make a difference?* Authors: Les Kirkup, Meera Varadharajan, Michael Braun, Andy Buffler and Fred Lubben.

ACDS T&L Conference presentation, Brisbane, 16th July, 2015, *OLT Seed Project: Matching the background of demonstrators with those of their students: does it make a difference?* Presenter: Les Kirkup.

STARS workshop, Melbourne, 1st July, 2015, *A hands-on exploration of learning through inquiry.* Authors: Les Kirkup, Meera Varadharajan and Michael Braun.

### Papers

Kirkup L., Varadharajan M., Braun M., Buffler A. and Lubben F. (2015) Matching the background of demonstrators with those of their students: does it make a difference?

STARS conference, Melbourne 2015: available from: http://www.unistars.org/papers/STARS2015/13F.pdf

Braun M and Kirkup L (2016) Non-physics peer demonstrators in undergraduate laboratories: a study of students' perceptions *European Journal of Physics* vol 37, 015703.

Kirkup L, Varadharajan M and Braun M (2016) A Comparison of Student and Demonstrator Perceptions of Laboratory-Based, Inquiry-Oriented Learning Experiences International *Journal of Innovation in Science and Mathematics Education* (in press).

## Key findings from UTS data

From the longitudinal survey administered at UTS we found there was a negative correlation between students' perceptions of the help and encouragement they received to think deeply about the experiment and the number of years of post-school physics experience of the demonstrators. In brief, those demonstrators with only a year or so post-high school physics and including peer demonstrators drawn from the same disciplines as the students were seen to be more helpful and encouraging of deep thinking than those with seven or more years of post-high school study of physics. The analysis showed that the difference was statistically significant at the 0.05 significance level. The fact that peer demonstrators were perceived to be at least effective at assisting students to think deeply about the experiments is evidence validating their introduction into the first year laboratory and may be one of the most significant findings of this study.

From the custom surveys administered to students at UTS, we found significant differences between students' and demonstrators' perceptions of interactions in the laboratory. Overall, the demonstrators appear to adhere to the principles of an inquiry-oriented model of learning, though there are indications that several may be uncomfortable with some of the consequences flowing from the adoption of the model. On the other hand, the model adopted by many students is that of direct instruction even though they may recognise inquiry-type experiments encourage deeper level engagement in their interactions with the demonstrators. There appear to be several reasons for the contradiction, including ineffectively managed expectations, lack of conviction in the validity of the inquiry model and prevalence of the direct instruction model in students' prior and concurrent laboratory experience.

Semi-structured interviews carried out at UTS were successful at probing the students' and demonstrators' expectations, experiences, and views on the role of the laboratory and examining student reliance on demonstrators. The interviews revealed two conceptions of the laboratory, often held in some measure by all students and demonstrators, but the emphasis of which varied from student to student, and demonstrator to demonstrator. One conception could be described as functional and was held most strongly by those most comfortable with recipe-based experiments and adoption of a direct instruction model where a) what has to be done is spelled out in detail by the demonstrator or the laboratory manual and, b) more emphasis is expressed by the student on technical matters, such as how to plot graphs, or set up and be able to use equipment. The other conception, more aligned to learning through inquiry, emphasises activities and interactions which have as their goals students developing their own approaches to problem solving and the enhancement of concepts, applications of physics or exploration of phenomena.

Observations captured by video of students and demonstrators in the laboratory remain to be analysed, however we offer one comment based on the viewing of students working in a conventional physics laboratory at UTS in 2014 and other students working in UTS' new 'Superlab' in 2015 (which accommodates up to 240 students simultaneously). In the 2014 laboratories which were smaller but with more space per student, there was a greater flow of students around the laboratory and more student/demonstrator interactions than in the Superlab.

In response to student and demonstrator data gathered through this project, aspects of the PAN laboratory program at UTS and its delivery were modified between spring semester 2014 and autumn semester 2015. The intervention resulted in gains in student engagement and perceptions of the value of the laboratory. As an example, in autumn 2015, 87% of students agreed that the experiments increased their understanding of physics compared to 59% in spring 2014.

That this short study was able to identify issues impacting on student and demonstrators experiences and perceptions which in turn inspired a successful intervention is a persuasive endorsement of the methods adopted during the project.

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# Chapter 1: Project context, drivers and aim

## The importance of the laboratory in the undergraduate science curriculum

The undergraduate science laboratory is a rich learning space prompting and encouraging students to develop and enhance their experimental skills (Boud, Dunn and Hegarty-Hazel, 1989; Hazel and Baillie, 1998; Psillos and Niedderer, 2002) and where authentic scientific inquiry can occur (Hume and Coll, 2008). The laboratory is able to offer students opportunities to enhance their capacities in such areas as critical thinking, written and oral communication skills, working productively in groups and behaving ethically and responsibly (Hanif, Sneddon, Al-Ahmadi and Reid, 2009). The laboratory plays a major role in the undergraduate science curriculum, both for students destined to major in physics and others for whom interest, circumstance or career trajectory takes them along other paths. Students recognise the value of their experiences in laboratories, especially with respect to their exposure to research and inquiry. When asked in a recent study 'What do you value most from your background in science?' students placed high on their list, skills in observation, experimentation and quantitation (Harris, 2012).

## Shifts in students' undergraduate laboratory experiences

We are witnessing a substantial shift in the type of laboratory experience offered to science students. This may be traced to institutional, national and international pressures for change including:

- increasing student numbers (ABC, 2013; Norton 2013).
- reconsideration of pedagogies adopted in undergraduate laboratories, with an increasing emphasis on inquiry (Kirkup, Pizzica, Waite and Srinivasan, 2010; Cobern, Schuster, Adams, Applegate, Skjold, Undreiu, Loving and Gobert, 2010).
- Australia's Chief Scientist purposefully advocating students be given insights into processes by which scientific knowledge is created and challenged (Office of the Chief Scientist, 2012).
- the development of Threshold Learning Outcomes by the Australian higher education community (Jones, Yates and Kelder, 2011) which have placed an emphasis on inquiry and problem solving in the undergraduate science curriculum (Kirkup and Johnson, 2013).
- the potential of inquiry to engage students, thereby arresting student attrition prevalent in science courses (Pitkethly and Prosser, 2001).
- the emergence of 'superlabs' in science faculties in Australia and around the world, in which many students operate simultaneously in a high-tech learning space (Hinton, Yeoman, Carvalho, Parisio, Day, Byrne, Bell, Donohoe, Radford, Tregloan, Poronnik and Goodyear, 2014).
- changes in the Australian Science Curriculum from K–12 (National Curriculum Board, 2009), which are bringing increased emphasis on science inquiry skills.

## Challenges for student learning in the laboratory

Despite the promise of the laboratory as an inspiring and effective learning environment, there is a history of criticism of what it delivers (Bless, 1933; White, 1996). For example, there is evidence that student experiences in the laboratory fail to live up to their expectations. The national significance of this problem was highlighted in an ALTC-funded report (Kirkup and Mendez, 2009) 'Forging New Directions in Physics Education in Australian Universities' (FNDPEAU), which showed students' experiences at almost all of the 22 universities in the FNDPEAU collaboration fell significantly below student expectations, prompting the recommendation that[1] [the physics community] *Recognise that the laboratory experience of students in first year physics subjects … across the majority of the tertiary physics institutions in Australia is a matter of concern, demanding urgent action.*

The reasons for widespread student dissatisfaction with the first year physics laboratory experience remain unclear and are likely to vary from course to course and institution to institution. However, there is little doubt that the demonstrator plays a pivotal role in creating and maintaining a positive and productive learning environment. Rice et al. (2009) found that for many students, "*demonstrators had the power to make a lab a great or a miserable experience"* and recommended a project be undertaken to "*promote change in the system of laboratory demonstrating*".

More recently, a report (O'Toole, 2012) commissioned by the Australian Council of Deans of Science (ACDS) recognised the importance of the laboratory for promoting authentic, inquiry-based learning persistently advocated by Australia's Chief Scientist (2012). The report states: *The impact of the challenges posed [by promoting inquiry based learning] justifies investment in the development of demonstrators' competencies, both at the individual and group level, to realise the potential of science teaching laboratories.*

## Institutional driver for this project

In the first year physics laboratories at UTS there is an emphasis on learning through inquiry (Kirkup, 2015). A demonstrator supporting experiments with an inquiry focus or emphasis is expected to assume the role of a facilitator rather than that of a teacher who provides student with detailed instructions on how to carry out an experiment (Roehrig, Luft, Kurdziel and Turner, 2003). Recognising this, and acknowledging the positive impact that students can have on the learning of their peers (Dawson, van der Meer, Skalicky and Cowley, 2014), the School of Physics and Advanced Materials (SPAM) at UTS introduced peer-demonstrators into the first year physics laboratories. The impact of the demonstrators on student perceptions of the comparative effectiveness of peer and non-peer demonstrators, for example in promoting deep learning was tracked (Braun and Kirkup, 2016). The work revealed a systematic trend indicating that peer demonstrators are perceived by students as more helpful and more effective at promoting deep learning than non-peers. This finding was a driver for this project.

The physics department at the University of Cape Town was also keen to explore student/demonstrator interaction, with a view understanding and enhancing the engagement to the benefit of student learning and had already initiated a study in this area

[1] http://www.physics.usyd.edu.au/super/ALTC/documents/ALTC-Report.pdf

prior to this project beginning[2]. The fact that the laboratory learning environments and philosophies underpinning the laboratory programs are quite different at UTS and UCT was expected to lead to findings that would be applicable beyond the two institutions. The two institutions have this in common: both UTS and UCT have large numbers of students underprepared for physics-based tertiary study, with many students taking physics as a service subject.

Our premise is that improved understanding of the factors contributing to the nature of student-demonstrator interactions will lead naturally to improved strategies for recruiting and professionally developing demonstrators. This in turn will enhance student engagement and satisfaction with first year laboratory work, facilitating a reduction in student attrition in the first year of university, which can typically exceed 20-30% (see for example Hinton, 2007).

## Aim

By examining student and demonstrator experiences and perceptions of the undergraduate physics laboratory we wished to enhance the value to students of undergraduate physics laboratories. More specifically, our aims were to:

- examine the effect of alignment between the background, ambitions, and views on teaching and learning of students and their demonstrators on student engagement and satisfaction.
- explore students' and demonstrators' views about learning and teaching in the physics laboratory and how these views about learning and teaching manifest themselves in student-demonstrator interactions.
- investigate aspects of student-demonstrator interactions students consider helpful in increasing their engagement with laboratory work.

As a result of the examination, we intend to advise on demonstrators' recruitment, induction and professional development as well as offer commentary on issues impacting on student experiences in the undergraduate laboratory.

[2] Curtin University was also a partner in the original application for funding from the OLT. Before this project began, the team member from Curtin left the university. As a consequence, and after advising the OLT of the situation, Curtin's involvement in this project came to an end.

# Deliverables

The intended deliverables of this project included:

- a final report with recommendations which will be made available in several forms including on the Inquiry Oriented Learning in Science website http://www.iolinscience.com.au/ .
- dissemination of the project, its methodology and findings through established national teaching and learning networks.
- promotion of project findings on the ACDS Teaching and Learning Centre website.
- delivery of a national workshop.
- presentations of the work and its findings at national and international conferences including the STARS conference and the ACDS Teaching and Learning Conference.
- a paper in an international peer-reviewed physics education journal detailing aspects of the project.

# Chapter 2: Approach and methodology

## Overview

Central to this project is the exploration of student/demonstrator experiences. This exploration comprised three phases. The phases overlapped as well as created opportunities to evolve during the period, leading to unexpected project findings.

1. Survey/interview design and ethics approval
2. Data collection phase
3. Analysis, review and development phase

Project dissemination occurred mainly in the second half of the project through various modes including presentations at conferences, papers in international journals and a website.

## Survey/Interview design

Ahead of this project, UCT carried out open-ended interviews with demonstrators and students with different backgrounds at UCT Physics about their experiences with the laboratory sessions. The approach adopted in the interviews, and the questions posed to students were adapted for use at UTS. Other questions explored the views of subject coordinators and senior academics and formed part of semi-structured interviews carried out at UCT.

In order to explore and compare student and demonstrator experiences, perceptions and interactions in first year laboratories at UTS we employed several complementary methods: UTS students feedback surveys, electronically administered which we had first adapted in 2011 to investigate student perceptions of their demonstrators; paper-based surveys of students and demonstrators; structures interviews, and; observations, captured through video of students and demonstrators working together in the laboratory.

### Centrally administered student feedback surveys

In common with other institutions, UTS administers online student feedback surveys (referred to as SFS surveys at UTS) at the end of each semester. Questions related to the study of student perceptions of demonstrators, responded to on a Likert scale from *strongly disagree to strongly agree*, included:

- *The [principal/assistant] demonstrator was well prepared to help me with my work.*
- *The [principal/assistant] demonstrator encouraged me to think deeply about the experiments*.
- *The principal demonstrator gave me good feedback on my work.*

These extra survey questions were developed in 2011 and were administered to students from the medical, biological and environmental sciences enrolled in the subject, Physical Aspects of Nature (PAN) at UTS each semester from 2011 onwards, including the period of this Seed project.

## Paper-based surveys of students and demonstrators

Surveys are used to probe students' perceptions of their learning experiences and provide valuable feedback to practitioners and researchers (Barrie, Bucat, Buntine, Burke da Silva, Crisp, George, Jamie, Kable, Lim, Pyke, Read, Sharma and Yeung, 2015). A short paper-based survey exploring the processes undertaken in the laboratory as well as outcomes of the laboratory experiences was administered to all students enrolled in a first year physics subject. A paper-based survey was chosen so as to maximise the response rate.

> Closed items were responded to on the Likert scale of strongly disagree to strongly agree. Other items on the survey allowed for free response.

Similar and complementary items to those on the student survey were included on a paper-based survey administered to demonstrators. Table 1 contains some items from the student and demonstrator surveys. Surveys for students and demonstrators can be found at http://www.iolinscience.com.au/demonstrators-students/resources/

Table 1: Sample items from student and demonstrator surveys

| Type | Students | Demonstrators |
|---|---|---|
| Closed | I was comfortable asking the Principal/Assistant demonstrator questions about the experiment | Generally, I was comfortable answering questions about the experiment |
| Closed | Overall, the demonstrator made an important contribution to my learning in PAN labs | Overall, I think I made an important contribution to enhancing students' learning experience in PAN labs |
| Open | Please write a few words on how the demonstrator most helped you in your learning | Please write a few words on what you see as the most important thing you did to help students learn in PAN labs |

The School of Mathematical and Physical Sciences (SMaPS) at UTS employs principal and assistant demonstrators who assume different roles in supporting students in the laboratory. The differences are relevant to this project. The principal demonstrator either possesses a PhD in physics or is working towards one. She or he has primary responsibility for managing the laboratory, introducing experiments to the class, assessing the students' laboratory-based work and assisting students throughout the laboratory session. The assistant demonstrator is generally a senior undergraduate or honours student with a more limited physics background than the principal demonstrator. The assistant demonstrator support students throughout the laboratory session, but has no assessment or organisational responsibilities. The student survey included questions specific to each category of demonstrator.

## Semi-structured interviews

While surveys are able explore the experiences, perceptions and satisfactions of students (Kuh, 2003), the project team judged the surveys would be complemented, and the findings of the surveys validated, by a more nuanced approach to this exploration. More specifically, it was regarded as essential that the student voice be heard directly in order to examine more thoroughly the beliefs, concerns, experiences and attitudes of students. It was anticipated that the interviews would be a source of rich insight into the experience and touch on matters that we had overlooked or given insufficient attention to, but that were prominent in the minds of students and/or demonstrators.

Informed by work that had been carried out at UCT, semi-structured one-on-one interviews were designed and conducted involving students and demonstrators in PAN at UTS. Through the interviews and their analysis we wished to establish the range of conceptions of the role of the laboratory and that of the demonstrator as held by each of the students and demonstrators we interviewed. There was an ambition to build a bigger picture of the range of these conceptions held collectively by students and demonstrators. The approach adopted has some similarity with phenomenographic methods (Akerlind, 2005). These methods strive to establish, often through semi-structured interviews in which a particular catalyst for conversation is focussed upon (Wilson, Åkerlind, Francis, Kirkup, McKenzie, Pearce, and Sharma, 2010; Kirkup et al., 2010), the variation in conceptions, understanding or ways of experiencing some phenomenon (Marton and Booth, 1997). It should be emphasised that, though our approach is similar to that adopted in phenomenography, there was no attempt to adopt that methodology rigorously.

The aims of the student interviews were to: understand what students perceived to be the purpose of laboratory work and how they learnt in the environment, and; student views and perceptions of the demonstrators and the support they offered in the laboratory. Students had the opportunity to discuss the challenges faced in learning and doing laboratory work and to suggest ways to improve their learning experience. A similar line of questioning was adopted for the demonstrators to determine their views on student learning and what could be done to enhance students and demonstrators' experiences of the physics laboratory.

Examples of interview questions addressed to students included "What are your views on the role and relevance of physics to your degree and career?"; "What are your learning influences in laboratory work?", and ; "What in your view is the role of a demonstrator and what kind of attributes should they possess?" Students were prompted to explain their learning process. Questions such as "Could you briefly describe a recent experiment or procedure followed in PAN labs" were used to gather further insight into ways they understood, approached and learnt from their laboratory experiences. Conversational style interviews allowed for probing more deeply into participants' views and perceptions through prompts such as "can you describe that a bit more" or "please tell me why you feel this way".

## Laboratory observations

It is likely that student and demonstrator self-reporting of their activities in the laboratory does not capture all the dimensions of student/demonstrator activities and interactions. The project team determined that a 'fly on the wall' approach using an unobtrusive camera would capture events and activities that may not emerge during the interviews. Students and demonstrators gave informed consent for the videoing and they were advised that the video would be used for research purposes only.

A video camera was placed at a discrete vantage point within the laboratory to capture the movements of those in the room for the duration of the whole laboratory session. Our intent was to observe the frequency and length of interactions between students and demonstrators, student engagement while performing experiments and generally identify critical incidences that take place in student learning and demonstrator teaching.

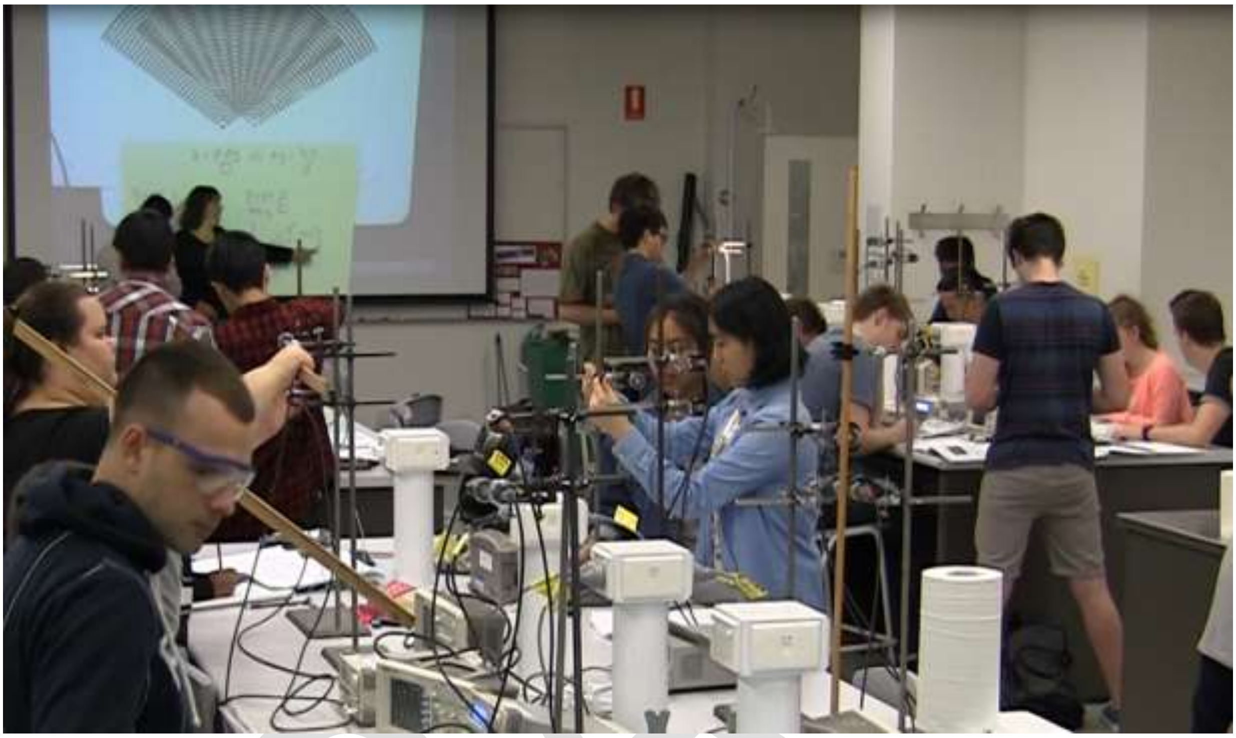

Figure 2: A still from PAN laboratory session videoed in spring semester 2014 at UTS.

A total of 5 PAN laboratory sessions were recorded each of duration two and half hours in spring semester 2014. The recording took place during the final experiment in the laboratory program.

## Data collection

**University based surveys:** Surveys (electronic) were administered and analysed by the Planning and Quality Unit (PQU) at UTS at the end of spring semester. Response rate was approximately 30%.

**Project focussed Surveys**: Surveys (paper-based) of students and demonstrators took place at UTS in the final week of laboratories. All students were asked to complete a consent form before they completed the survey (and were given the option not to hand in the survey) 417 (76% of all students enrolled in PAN) students and 18 demonstrators (82% of all PAN demonstrators) completed the survey. Out of the 18 demonstrators, 9 were principal demonstrators, and 9 were assistant demonstrators.

**Interviews at UTS**: The interviews took place at UTS at the end of teaching in the spring semester 2014, but before students took their end of semester examinations. 15 students took part in the interviews and 11 demonstrators (6 principal demonstrators and 5 assistant demonstrators). After advising the participants of the project and asking them to consent to being interviewed, the interviews were recorded and later transcribed for analysis. Each interview was between 20 and 60 minutes in duration, with the demonstrator interviews generally longer than those of the students.

The interview began by putting participants at ease by asking general questions (for example, what was the degree being undertaken by the student) before proceeding to questions of a specific nature. For example, the following questions were put to student participants which gave them opportunity to open up and provide critical information of value to the study: *What do you think is the role and relevance of physics to the degree you are undertaking? ; Before you started the course, I am curious about what you expected the course to be like?,* and*; How did you feel once you had started the course?*

Questions on participants' perceptions on laboratories and how they learn were probed before moving on to questions about demonstrators. Participants were given the opportunity to describe their learning process ('how they learn') in various ways. Examples could be participants describing the procedure they followed while conducting an experiment (in steps) or describing what happens in a typical laboratory session from the beginning to the end.

**Interviews at UCT:** Student and demonstrator interviews were carried out at UCT in April 2015 by the project leader. Five demonstrators and five students were interviewed. The same interview structure and questions were adopted as for the UTS interviews. Opportunistically, and because we believed we were missing an important voice of stakeholder that impact on the student experience and student/demonstrator interaction, interviews were carried out with the head of department and 3 other developers/convenors of the first year physics labs at UCT.

Questions asked of the HoD and developers/convenors included; In what way are lab programs valuable to students, and: what are the most important traits of demonstrators?

**Videoing laboratory classes**: Five PAN laboratory classes were videoed during their final experiment. The videos were of approximately 2.5 hours duration.

## Analysis methods

University based surveys: Basic statistical methods were applied to establish the impact of several factors including the influence of demonstrator background (number years of formal study of physics of the demonstrator) and the gender of the demonstrator on mean student responses to the survey items.

Project focussed Surveys: each response to a closed item on the survey was scored using a 5-point Likert scale, where: 1=*Strongly disagree*, 2 = *Disagree,* 3 = *Neutral,* 4 = *Agree*, and 5=*Strongly agree*. To compare student and demonstrator responses to complementary items on the survey, for example *I relied on the demonstrator to tell me how to do the experiments* (item on student survey) and *Most students relied on me to tell them how to do the experiments* a two-tailed t-test was applied to test a null hypothesis that the means of samples were drawn from the same population at the 0.05 significance level. Analysis of the open-ended questions involved a qualitative approach. A process of constant comparison for recurring words and emerging patterns (Lincoln and Guba, 1985) and open coding (Strauss and Corbin, 1990; Wiersma and Jurs, 2005) was used to categorise the data. The responses for each item were analysed, following a process of data organisation, data reduction, coding and categorisation. The results of the analysis were used to relate the open- to the closed-ended responses.

Interviews: Student and demonstrator interview transcripts were examined for commonalities and variations in their respective expectations and perceptions with respect to the laboratory and the factors that impacted on those perceptions. Responses to the interviews question were compiled to identify significant features. In addition, similar responses were grouped or categorised to understand how participants described their perceptions. The groupings were supported by extracts from the transcriptions.

Observations of students and demonstrators in the laboratory. To date these have yet to be analysed. The intention is to adapt a protocol for analysing student-demonstrator interactions in the laboratory developed through an ALTC fellowship awarded to the project leader (Kirkup et al., 2011).

# Chapter 3: Findings, outputs and dissemination

## Findings

A statistically significant finding from the centrally administered SFS surveys at UTS was that the mean student scores (out of for 5) for the items *The [principal/assistant] demonstrator was well prepared to help me with my work, The [principal demonstrator/assistant] encouraged me to think deeply about the experiments* decreased as the years of formal study of the demonstrators increased[3]. That is, demonstrators with a modest background in physics scored well in the SFS surveys compared with those with many years of experience. Another statistically significant finding was that the mean score awarded to assistant demonstrator for the level of help they provided to student and their preparedness to help was greater than that of the principal demonstrators, as shown in Figure 3.

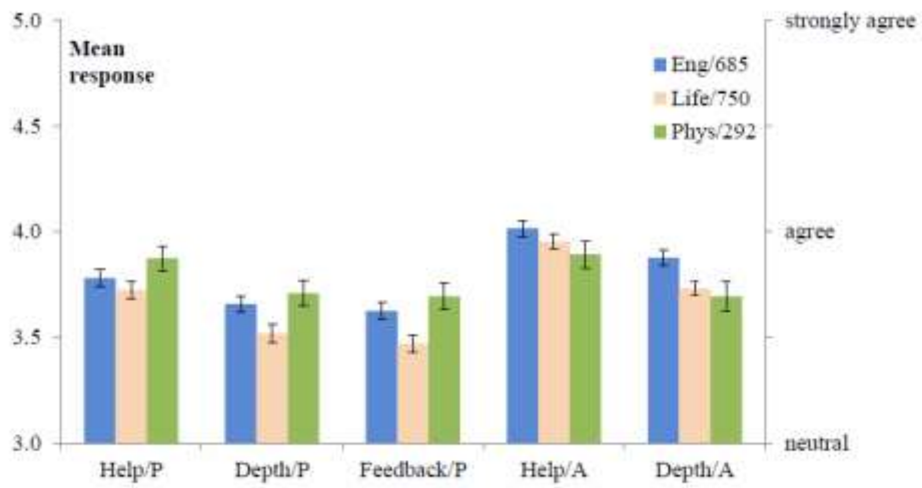


Figure 3: Mean response of students studying first year physics for engineers (Eng), physics for physical science students (Phys) and physics for life science students (Life). The categories have the following meanings; Help/[P/A] is help provided by principal/assistant demonstrators, Depth/[P/A] is encouragement to think deeply about experiments by principal/assistant demonstrators and Feedback/P is feedback given to student by the principal demonstrator.

The pink bars in Figure 3 relate to PAN student responses. For comparison, the blue and green bars represent responses for cohorts of students enrolling in two other subjects at UTS: physics for engineers (Eng), and physics for physical science (Phys) students respectively. Though not part of this study, it is worth remarking that similar statistical differences between student responses to assistant and principal demonstrators apply to these cohorts, suggesting that findings with respect to PAN students and their relationships with demonstrators are widely applicable.

The custom designed student survey for this project comprised 14 closed statements and 3 open-ended questions. Closed statements included:

[3] More detailed information on the findings can be found in Braun and Kirkup, 2016.

*I was encouraged to think deeply about the experiments by the Principal/Assistant demonstrator, and; I was comfortable asking the Principal/Assistant demonstrator questions about the experiments.*

Responses to the open-ended questions in the demonstrator surveys reveal that more assistant demonstrators (than principal demonstrators) describe helping students at a deep/conceptual and higher order thinking level. Examples of such responses are:

- ✓ *[I get the students to] Discuss the underlying physics and … to think deeply about the experiment.*
- ✓ *[I] encourage them to go beyond what was stated in the experimental protocol.*
- ✓ *[I] explain the significance of the experiments and how it related to applications/fields. Talk about personal experiences in science.*

In support of this finding, a higher percentage of students reported in the open-ended responses that they were encouraged to think deeply about the experiment more often by the assistant demonstrator as compared to the principal demonstrator.

With regard to the demonstrator's contribution to student learning, a large proportion of students praised the attributes and inter-personal skills of their assistant demonstrators. For example, the students described the assistant demonstrators as being *more approachable and helpful* and possessing an *awesome personality.*

These qualitative findings support the analysis of the university administered SFS surveys that found the assistant demonstrators to be more highly rated than the principal demonstrators in terms of readiness to help and encouragement of deep learning. These findings have been published (Kirkup, Varadharajan, Braun, Buffler, and Lubben, 2015).

Further analysis of the surveys revealed two major issues with respect to students view about the work they did in the laboratory: the written material provided to students, and student dependency on demonstrators. With respect to the former, the nature of the inquiry-oriented experiments meant that the designers provide a skeleton description of the experiment. The surveys and the interviews revealed that neither the students nor the demonstrators were comfortable with a sparsely-scripted laboratory manual and were quite critical of its clarity and the support it gave.

Analysis of the surveys revealed that demonstrators believed students relied on them to tell them how to proceed with experiments. This is indicative of students' expectation of a direct instruction model in their interactions with the demonstrators (Boud et al., 1989).

Most demonstrators referred to encouraging the students to "*think deeply"* about the experiments, "*encouraging* [students] *to go beyond what was stated"*, and were happy to "*discuss the underlying physics"*. Such views were as prevalent among the assistant demonstrators as among the principal demonstrators despite the former having had a typically shorter exposure to the physics discipline. Details of the survey results have been submitted for publication (Kirkup, Varadharajan and Braun, 2016).

There was consistency expressed by students (S) and principal (P) and assistant (A) demonstrators through the semi-structured interviews on the purpose of the laboratory. In broad terms, the purposes can be categorised as:

Demonstrate some important physics phenomenon (linked to lectures) eg *to reinforce the theories we learn in the lectures* (S) , *practically showing how concepts work....*(A)

Developing skills (such as communication, manipulative and analysis skills) eg. '*develop skills (eg report writing, inter-personal)'* (S) *experimental skills...graphing, being able to write down all measurement and collate into a report* (A)

Going deeper into their learning '*So we get a better understanding of the concepts'*, *to promote inquiry based learning* (P)

These views are well aligned with the literature (for example Boud et al., 1989, Hazel and Baillie, 1998).

The interviews also allowed for the exploration of the factors that influenced student learning including their interaction with demonstrators: *Demonstrators have the influence on how you take an approach to the Prac...really does influence your learning, the demonstrator can have a large impact because the amount of information you can get out of them is obviously going to impact how much you learn*, *If they are approachable and friendly, it makes a lot easier*.

Insight into student/demonstrators interactions and their experiences in the laboratory will form the core of a paper to be prepared for publication in an international journal.

The outputs of this project include conference papers, peer-reviewed papers, conference presentations and resources developed for this project. These resources, along with details of the project aim, methodology, findings and details of dissemination, can be found at http://www.iolinscience.com.au/demonstrators-students/resources/ . Details of other products which also supported project dissemination can be found in Chapter 4.

## How the project used and advanced existing knowledge

Laboratories remain a vital component of the undergraduate science curriculum. With student numbers increasing in many universities and the increasing influence on the curriculum of standards and learning outcomes there has been a new impetus to reconceptualise the role of the laboratory in learning. We have be influenced by existing knowledge in this area which has been built up over several decades, including monographs, such a 'Teaching in laboratories' by Boud et al. (1989) and 'Improving Teaching and Learning in Laboratories' by Hazel and Baillie, (1998).

This project utilised the evidence and extended findings of student experiences in laboratories acquired through Carrick and ALTC fellowships awarded to the project leader (Kirkup, 2009; Kirkup, 2013). Survey items developed as part of the 2013 fellowship were adapted for use in this project. This project is promoting and contributing to the reconceptualisation of the role of the laboratory, and in particular, the role of the demonstrator, in part through building on work carried out nationally, for example the influential ALTC funded study by Rice et al. (2009) which focussed on 'Tertiary Science Education in the 21st Century'.

This project supports and adds weight to findings and recommendations of an ACDS-funded study 'Demonstrator development: Preparing for the Learning Lab' by O'Toole (2012) for example that 'demonstrators should encompass a wider range of experience than university research' and subject coordinators/convenors should 'encourage feedback from demonstrators'. O'Toole emphasised that the pool of demonstrators should be broadened to include 'experienced science professionals'. The study has indicated that demonstrators close in age and disciplinary persuasion are also deserving of consideration for inclusion in the pool of demonstrators as they are recognised by students as encouraging deep learning.

The methods adopted in this project were informed and in some cases underpinned by the work of others that have devoted time and energy to maximising the value of laboratories to students. As examples,

- the review of the value of peer-instruction Dawson et al. (2014). Our study points to peer-instruction being valuable within the context of the laboratory.
- the challenge of encouraging students and instructors to embrace learning through inquiry in the laboratory, as described by Hume and Coll (2008). The instructors in Hume and Coll's study were teachers. We found in this study that though inquiry has been built into and throughout a laboratory program, unless the right messages are sent to students and demonstrators in a persuasive, coherent and timely manner the perceptions of the purpose of the laboratory and its effectiveness may be compromised.
- Bruck and Towns (2009) considered how to prepare students to benefit for inquiry based activities including demonstrators adopting a more facilitative role. This study supports that suggestion (which also has been made elsewhere many times, see Roehrig et al. (2003)). What we have learned through this Seed project is that it is the whole laboratory program that must be reviewed and in some cases reconceptualised if that program is to be successful. This might include rigorously reviewing materials prepared for student and demonstrators, making persistent links between other facets of the curriculum, such as to the lectures, emphasising the relevance of the laboratory activities to the student current studies and possible future career trajectories, and giving demonstrators just in time advice regarding the experiments and their purpose. This study showed that accomplishing these things makes an impact on student perception of the value of the laboratory.

## Disciplinary and interdisciplinary linkages

Through conference attendance, OLT event, academic networks, and contacts with academics at UTS linkages have been forged with groups and individuals including:

Kelly Matthews, Senior Lecturer, Curriculum**,** Institute for Teaching and Learning Innovation UQ. Kelly's OLT fellowship is reconceptualising the role of students in science degree programme curriculum. Kelly is eager to explore with the project team the role that students can have in developing and co-delivering laboratory programs

Georgina Barratt-see, Manager, U:PASS, Higher Education Language & Presentation Support, UTS It is timely for the role of peer support in laboratory to be placed front and central. The project team is linking with Georgina to progress peer support in the laboratories at UTS.

Mauro Morcerino, Associate Professor, Department of Chemistry, Curtin University. Mauro's OLT fellowship '*Enhancing learning in the laboratory: identifying and promoting best practice in the professional development of demonstrators.* Mauro's fellowship has much in common with this project. The sharing of finding between his fellowship and this Seed project will bring emphasis to the importance of demonstrators as facilitators of student learning.

Australian Council of Deans of Science. Through contact with the Director of ACDS TL centre, Professor Liz Johnson, details of this project have been placed on the ACDS website. We anticipate that future developments will also be reported on this website.

## Factors contributing to the success of the project

Recruiting Meera Varadharajan as a part-time project officer with skills that complement those of the principal investigators has been particularly advantageous to the project. Meera brought much-valued expertise and a skill set well-matched to this project.

Being able to utilise the existing infrastructure of survey collection and analysis (in our case, the University's Planning and Quality Unit) has allowed us to focus on the content of the evaluation tools rather than the mechanics of survey production and data gathering.
It is particularly important in projects of a short duration that interventions and evaluations be implemented in a short time scale. Achieving tight timelines is made easier if a principal investigator has a substantial teaching role in a suitable subject (in our case, one of us was the subject coordinator and lecturer).

Events can, and often do, occur that require the project plan to be revised. In our case, two changes that initially appeared to be impediments to the project's progress, were turned into opportunities. One of our overseas principal investigators was appointed into a senior management position and was no longer in a position to run a planned student survey. We adjusted our approach and implemented interviews with laboratory teaching staff with one of the UTS investigators travelling to Cape Town to run the interviews with students, demonstrators and subject coordinators. The other change was the displacement of the teaching laboratory into a "superlab" facility. While the different physical environment of the superlab makes it more difficult to carry out longitudinal comparisons, we took the opportunity to evaluate the impact of the superlab on the carriage of practical classes by adding a superlab-related open-ended question to the student survey. Our preliminary work will be useful to us in adapting our classes to the new environment. At a time when many universities are considering superlab facilities, our findings may assist others in the sector in framing evaluation proposals.

## Dissemination

Formal dissemination of the project and its findings occurred/is occurring through a range of modes targeting different audiences as shown in Table 2.

Table 2: Modes of dissemination and the corresponding target audience.

| Mode | Target |
|---|---|
| Project background, aim, methodology, findings on the IOLinscience Website http://www.iolinscience.com.au/ | University academics, learning developers and designers in Australia and worldwide with an interest in enhancing student/demonstrator interactions, particularly in inquiry-oriented laboratory programs. |
| Presentation and workshop at the STARS workshop http://unistars.org/docs/STARS_2015-Program.pdf | The broad academic community (i.e. broader than the science community within universities), including academic developers and those that support student transition to university . |
| Paper at the STARS conference http://www.unistars.org/papers/STARS2015/13F.pdf | University academics, learning developers and designers in Australia and worldwide. |
| Papers in international journals, eg the European Journal of Physics | The international physics community committed to supporting student learning in universities |
| Presentation at the ACDS Teaching and Learning Conference (Brisbane, July 2015) | Associate Deans, Teaching and Learning (and equivalent) from science faculties around Australia. |
| Description of Seed project on the ACDS Teaching and Learning Centre website http://www.acds-tlcc.edu.au/ | Academics designing and teaching the undergraduate science curriculum in Australia |
| Project Fliers | Associate Deans Teaching and Learning |
| Final project report | Science academics. |
| Invitations to present in 2015/2016 on the project at invitations of Kelly Matthews (University of Queensland), Mauro Morcerino (Curtin University) and Karen Burke da Silva (Flinders University) | Front line full time and casual academics with responsibilities for delivering laboratory programs. |

# Chapter 4: Lessons learned and future directions

A successful implementation of an inquiry-oriented model of learning in a laboratory requires the experiment designers, the demonstrators and the students to be “on the same page”. Our results indicate that this is not necessarily the case. The students, guided by prior experience and perhaps laboratory classes in concurrent subjects that follow a direct instruction model, do not recognise, or are confused about, the expectations placed on their work and interactions with demonstrators. The demonstrators, either by virtue of personal preference or, more likely, in response to the pressure of keeping to the timelines, deviate from the inquiry model. The experiment designers may not be involved in reviewing and modifying the practical class to better fit in with the learning objectives. In overcoming these difficulties, an ongoing practical development process is needed that involves all three parties. Professional development of demonstrators needs to communicate better the learning objectives and processes consistent with the inquiry-oriented learning. Students’ expectations need to be better managed involving both the lecturing and the demonstrating staff.

Our study of the effect of the separation (measured in the number of years of formal study) between the demonstrators and the students indicates that, in terms of helpfulness and engendering deeper engagement with the subject matter, the demonstrators with low separation (and therefore greater proximity to students in age, background, and academic aspirations) did no worse, and sometimes better, than their more experienced colleagues. The study validates in particular the use of non-physics major peer demonstrators in laboratories for non-physics students. This approach to recruitment offers the potential for improved engagement in such classes, where student motivation tends to be a common issues.

Students playing a role in the design and co-delivery of the curriculum is an exciting area likely to have growing impact on the teaching and learning landscape. It is timely for partnerships between students and academics/curriculum designer of the laboratory curriculum to be created and become manifest in higher education. This project has shown that peer demonstrators can effectively support the delivery of the curriculum, but it is time to expand student input and influence. We propose as a follow on from this project provisionally entitled ‘Students as learners, leaders and architects: reconceptualising curriculum design, development and delivery of student-centred, laboratory-based, activities’. The goal of the project would be to effect systemic enhancement of the student laboratory experience and learning by adapting and expanding existing and emerging work on student-centred curriculum design and delivery, learning outcomes, and the design of new laboratory learning spaces.

Many universities are introducing or are considering introducing large-capacity, multidisciplinary, computer-equipped and internet-enabled science laboratories (sometimes referred to as “superlabs”). Because the laboratory classes we studied moved from a traditional laboratory space to the superlab, we have acquired data that allow a preliminary comparison. The superlab cohort is much smaller than the traditional laboratory cohort, reducing the statistical power of the survey instrument. Nevertheless, initial indications are that the transition to the superlab (a) has not adversely affected the indicators of student engagement in an inquiry-based laboratory experience, and (b) students' open-ended responses to a survey item on the "learning experience in the Superlab" were generally positive although students commented on difficulties arising from the constraints of the physical architecture of the laboratory. This is an area requiring work in assessing the impact of the superlab architecture on the inquiry model of learning. Importantly, development of practical classes that makes optimum use of the superlab resources is needed.

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