The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The first Australian multidisciplinary workshop

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Abstract

Most science educators and researchers will agree that the laboratory experience ranks as a major factor that influences students' attitudes to their science courses. Consequently, good laboratory programs should play a major role in influencing student learning and performance. The laboratory program can be pivotal in defining a student's experience in the sciences, and if done poorly, can be a major contributing factor in causing disengagement from the subject area. The challenge remains to provide students with laboratory activities that are relevant, engaging and offer effective learning opportunities.

The Advancing Science by Enhancing Learning in the Laboratory (ASELL) project has developed over the last 10 years with the aim of improving the quality of learning in undergraduate laboratories, providing a validated means of evaluating the laboratory experience of students and effective professional development for academic staff. After successful development in chemistry and trials using the developed principles in physics and biology, the project has now expanded to include those disciplines. This paper will discuss the activities of ASELL and provide a report about the first ASELL science workshop held at the University of Adelaide in April 2010, present some views of academic and student delegates, and make comparisons with other workshops.

Introduction

Laboratory activities have an important and characteristic role in science curricula (Hofstein & Mamlok-Naaman, 2007). Science educators have suggested many benefits of laboratory work in terms of both knowledge and skill development (Bennett & O'Neale, 1998; Hegarty-Hazel, 1990; Hofstein & Lunetta, 1982, 2004; Moore, 2006). It is acknowledged/accepted that effective experiments do not utilise a 'follow the recipe' structure (Domin, 1999) where students can "go through the motions... with their mind in neutral" (Bennett & O'Neale, 1998, p. 59). Experiments need to be designed to support student autonomy whilst allowing for cognitive engagement (Skinner & Belmont, 1993). This can be achieved by having students work together collaboratively to solve problems (Shibleym & Zimmaro, 2002), incorporating inquiry-based learning activities (Green, Elliott, & Cummins, 2004), or designing open-ended investigations (Psillos & Niedderer, 2002) (noting that pure discovery activities tend to be ineffective as they lack structure (Mayer, 2004)). Such activities not only improve motivation (Paris & Turner, 1994), but students can also scaffold each other's learning (Coe, McDougall, & McKeown, 1999).

Each year across 35 Australian universities, about 20,000 students undertake chemistry units (Barrie, Buntine, Jamie, & Kable, 2001a). Almost half of students time is spent on laboratory activities (Royal Australian Chemical Institute, 2005), and these figures are assumed to be similar in the domains of biology and physics. So it is important that the opportunities afforded by these learning environments are realised. A challenge facing many educators is to provide laboratory programs that are relevant, engaging, and offer effective learning opportunities within existing constraints. A further dimension of this challenge lies in the demonstration of the laboratory as a unique learning environment (Rice, Thomas, & O'Toole, 2009).

The Advancing Science by Enhancing Learning in the Laboratory (ASELL) project provides a multi-institutional, collaborative approach for improving the quality of undergraduate laboratories and providing effective professional development for academic staff. This paper will discuss the activities of ASELL and provide a report about the first ASELL science workshop held at the University of Adelaide in April 2010, present some views of academic and student delegates, and make comparisons with previous workshops.

History of the Project

The Australian Physical Chemistry Enhanced Laboratory Learning (APCELL) Project (Barrie, Buntine, Jamie, & Kable, 2001a, 2001b, 2001c) began in 2000 when a number of chemistry academics noticed increasingly high levels of student dissatisfaction with their undergraduate chemistry laboratory courses. It was also apparent that many of the academics who taught chemistry at the tertiary level were not familiar with educational research related to students' experiences in the laboratory. Therefore, the project team designed professional development activities that enhance both academic and student understanding of issues affecting student experiences in the laboratory. Research suggests that effective academic staff professional development, especially professional development that introduces new concepts, should meet five major objectives: it should (i) confront or address current academic staff beliefs and assumptions about learning; (ii) provide an evidence-based rationale for new methods; (iii) allow staff to experience a new pedagogy as a student; (iv) require academics to reflect as instructors, considering any situational barriers to implementing the new pedagogy; and (v) provide on-going support and follow-up as faculty implement new strategies (Froyd & Layne, 2008; Henderson & Dancy, 2007; Irby, 1996; Sandretto, Kane, & Heath, 2002).

In 2006 the team expanded the focus to include all aspects of chemistry – the Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) Project was formed (Buntine, Read, Barrie, Bucat, Crisp, George, Jamie, & Kable, 2007; Jamie, Read, Barrie, Bucat, Buntine, Crisp, George, & Kable, 2007; Read, 2006a, 2006b).

The ACELL project aims were pursued in a variety of ways, including:

- providing through our website a publicly-available database of experiments that met the predefined acceptance criteria, as well as all materials necessary for introducing these experiments to new institutions;

- organising and conducting workshops at which experiments were evaluated;
- providing professional development for chemistry educators through workshops, conferences, and departmental seminars;
- monitoring and reviewing the educational analysis of laboratory exercises;
- assisting practicing chemists to bridge the gap between chemistry and education by providing on our website resources relating to educational research using a framework and language accessible to practicing chemists; and,
- undertaking and publishing chemistry education research examining issues related to learning in the laboratory environment.

ACELL was intentionally designed to assist practicing chemists to improve the quality of their teaching in the laboratory environment. Most chemists at the teaching/learning interface are discipline experts, and are usually not well read in the education research. ACELL seeks to engage academics in reflecting on their own curriculum decisions, especially about the design of laboratory experiments (Brew & Barrie, 1999). As ACELL advocated a student-centred view of learning, students were included at every stage and in every aspect of the evaluation of submitted experiments. This approach ensured that the students' perspectives were integral to the development of an experiment and has proven to benefit both academic and student participants; teaching staff were reminded of the experience of being a student undertaking an unfamiliar experiment, whilst students gained insight into the educational complexities involved with laboratory work.

The Development of the ASELL Project

In 2007, the ACELL project team started to explore the possibility of applying the principles and processes developed in chemistry to other science disciplines. Exploratory workshops based on the ACELL process were held for physics (late 2007) and biology (early 2008). The success of these preliminary workshops in disciplines other than chemistry resulted in the establishment of ASELL in 2009. ASELL has four distinct goals:

1. to provide for the professional development of science academics by expanding their understanding of issues surrounding learning in the laboratory environment;
2. to facilitate the development of a community of practice of laboratory educators by providing mentoring in educational theory and practice, regular workshops, and a presence at scheduled education conferences;
3. to provide a sustainable mechanism, through involvement of the Australian Council of Deans of Science, to embed this cultural change as standard institutional practice; and
4. to conduct and enable research into learning and teaching in the laboratory environment.

It was expected that the core activity for achieving the first two goals would be through the experimental workshop model using the process for evaluation of laboratory activities developed in the A(P)CELL projects (as shown in Figure 1). Educationally-validated undergraduate experiments that meet pre-determined criteria will be published on an open-access website (www.asell.org – this site will also include all previously accepted APCELL and ACELL activities).

Since ASELL has evolved from A(P)CELL, there are many common elements. Those discussed below have been rebranded and integrated into ASELL, hence will be discussed as components of ASELL. One aim of the ASELL project is to make experiments publicly available. For this reason, a complete ASELL experiment submission consists of several parts. At a minimum, a complete submission will include:

- Student Notes – containing the background information and experimental notes which are provided to students who are undertaking the experiment in its home institution
- Demonstrator Notes – containing information and instructions for the supervision of students as they do the experiment. Such notes typically address common problems encountered, provide answers to set questions, present 'typical' data, and provide guidance on approaches to assisting students to achieve the stated learning outcomes.
- Technical Notes – containing all information required by technical staff in order to set up an experiment, including a list of equipment and chemicals, estimated costs, settings for instrumentation (if appropriate), safety measures that need to be taken in the laboratory, and any other information which technical staff might require.
- Hazard / Risk Assessment – this addresses both chemical and physical hazards associated with the experiment, as well as describe safety precautions.
- The ASELL Educational Template – this provides information on the context in which the experiment is run, the educational goals which it serves and how those goals are achieved, and an analysis of student feedback data providing evidence of students' perceptions of the experiment.

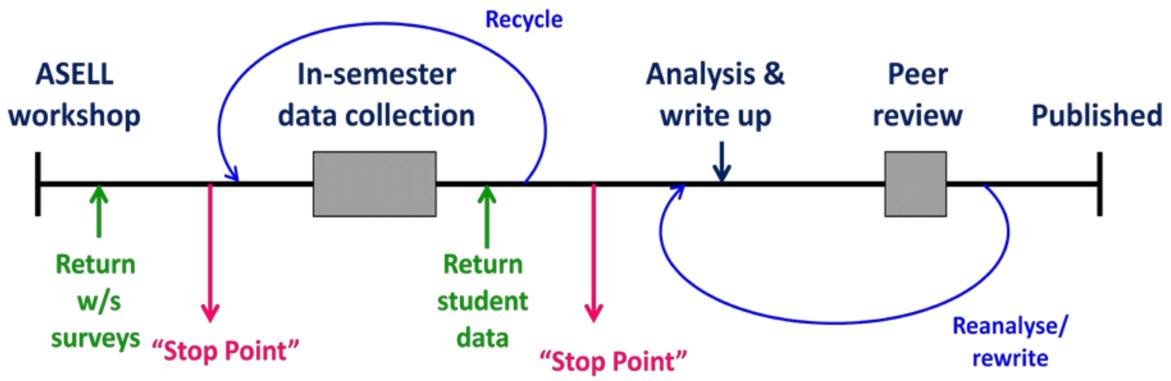

Figure 1: The ASELL experiment evaluation process (reproduced from Pyke, et al., 2010).

Experiment Evaluation Procedures

In order for an experiment to be accepted into the ASELL database, it must pass through a rigorous evaluation of both its scientific and educational merits. This evaluation process involves three distinct stages, and is intended to ensure that ASELL experiments are of benefit to the students who undertake them and are also easily transferred to other institutions that might wish to adopt them (see Figure 1). After successfully completing the ASELL process, academics who submit an experiment have the option of publishing the educational analysis of their experiment as a full journal paper (see "Stage Three" in this section for further details).

Student participation is integral to the testing and evaluation of experiments, as there is little point in evaluating any learning activity without taking into account the students' perspective. Transferability is also important as ASELL aims to assist in improving the quality of student learning in the laboratories of institutions beyond those directly involved with the project. The stages of the evaluation process are described below.

Stage One – Workshop Testing

Workshop testing of experiments is generally undertaken by teams consisting of both students and teaching academics from a range of institutions. The primary aim of running a workshop is the third-party testing of experiments. All delegates act as 'students' in undertaking the experiment, and are provided with the Student Notes and the initial draft of the first two sections of the Educational Template. The submitter of the experiment takes on the role of Demonstrator during this testing. Having completed the experiment (or a representative sample of it if the experiment is long), delegates complete anonymous surveys covering their experience of the experiment itself and their opinions of the Educational Template. The workshops held to date (APCELL, ACELL & ASELL) are shown in Table 1. Experimental workshops are those where laboratory work was carried out and experiments were tested under as realistic conditions as possible (3 hour lab, ~8 "students" per experiment). The non-experiment workshops consisted more of discussion sessions and did not have the laboratory component. The aims of the workshop testing phase are thus two-fold: firstly, this testing serves to demonstrate that the experiment is transferable to a new institution, by having it set-up and run away from its home laboratory. This ensures that the Technical Notes provide sufficient information, and that the Student Notes do allow those unfamiliar with the experiment to complete it successfully. Secondly, this stage of testing provides valuable feedback to submitters on the strengths and weaknesses of the experiment and the initial draft of the Educational Template.

Typically, an ASELL workshop includes time for group discussions of general educational issues related to learning in the laboratory, drawing on the expertise of the ASELL team and the collective knowledge and experiences of the workshop delegates, both student and academics. In addition, workshops usually provide an opportunity for submitters to also take on the student role, and thus to be involved in the evaluation of experiments other than their own. As a consequence, delegates gain insight into the purpose of the Educational Template from different perspectives, whilst having the opportunity for discussions on a range of experiments and educational issues. It is likely that many submitters will want to make changes to their draft Educational Templates following this experience, and this is both desirable and an intended part of the workshop process. For this reason, the only formal requirement following this stage is that the experiment has been tested and found to work/behave as expected – all documentation can be modified following the workshop, at the submitter's discretion. Experiments will not continue to the next stage of evaluation if the consensus of delegates who tested the experiment is that it does not work or is inconsistent with what was expected to happen; such a situation is extremely rare as submitted experiments have normally been run in their home institutions.

Table 1: Summary of past workshops from 2001 to 2010

Experimental workshop	Non-experimental workshop
February, 2001 (Sydney) – APCELL	July, 2000 (Canberra) – APCELL
November, 2002 (Melbourne) – APCELL	February, 2002 (Christchurch) – APCELL
February, 2004 (Hobart) – ACELL Chemistry	July, 2005 (Sydney) – ACELL Chemistry
February, 2006 (Sydney) – ACELL Chemistry	July, 2007 (Auckland) – ACELL Chemistry
January, 2007 (Adelaide) – ACELL Chemistry	October 2010 (Perth) - ASELL
November, 2007 (Sydney) – ACELL Physics	
April, 2008 (Adelaide) – ACELL Biology	
July, 2009 (Sydney) – ACELL Chemistry	
April 2010 (Adelaide) – ASELL Biology chemistry Physics (microbiology included in chemistry with help from biology)	

Stage Two – Student Feedback
ASELL adopts an evidence-based, and student-centred, approach to teaching and learning, and consideration of the students' perspectives is vital to such an approach. After an experiment has completed workshop testing, it is taken back to its home institution where any modifications that are needed can be made before student feedback data are collected. The data collected are students' perceptions of the experiment. ASELL has chosen the students' perceptions of their learning experience as the focus of this feedback, and has developed the ASELL Student Learning Experience (ASLE) survey to standardise this data collection. The ASLE instrument can be applied to any laboratory exercise, irrespective of the level or domain of the experiment, and thus provides a uniform approach to examining students' experiences. A member of the ASELL team supervises the administration of this survey, which can be distributed either electronically or on paper provided that the data collection is conducted in compliance with the Ethics Approval under which the project operates. The data is collated and analysed by the Project Manager. The data is returned to the submitting institution only after the end of the relevant semester so that students can feel secure that their responses can have no effect on their grades. The ASLE instrument includes both Likert scale and open-response items, and the student evaluation part of the Educational Template (section 3) must include a summary of the Likert scale data and a content analysis of the qualitative data from the open-response items.

Whilst student feedback data are essential if the evaluation of an experiment is to be evidence-based, the kind of data collected will depend on the questions it is intended to address – examining students' perceptions is significantly different from attempting to measure what students have actually learned during the time they spend doing the exercise. For example, students' learning about chemistry occurs as a result of their interpretations of the full range of activities they undertake – from lectures to tutorials to laboratory work to private study – and to attempt to investigate the influence of a single laboratory activity is very difficult; even a well designed study can produce results that are potentially misleading. Standard ASELL procedure involves conducting the ASLE survey at the end of an exercise, which is the ideal time to gather information on students' perceptions whilst experiences are fresh in their minds; such timing is not well suited to measuring what is learned as any learning resulting from post-laboratory activities such as report writing and reflection would be omitted. If an experiment does not perform as well as hoped, that experiment can be modified again and data recollected a second or subsequent time. This is shown by the "recycle arrow" in Figure 1. In addition, measuring learning raises the challenge of establishing a baseline for comparison, which can be problematic, especially as approaches such as pre-testing risk altering the learning environment by unduly focussing students attention onto particular aspects of the activity (in effect, the act of measuring can change the result). As has been previously mentioned, ASELL is primarily intended to engage practitioners rather than experienced science education researchers, and for all of these reasons the ASLE survey instrument is designed to examine students' perceptions.

In addition to the advantages described above, focussing on students' perceptions also fits with the professional development aims of the project in that it provides academics with insight into the students' perspectives and lived experiences; as a result, academics have a greater understanding of their students, which assists them to critically self-assess what their students might gain from a proposed teaching sequence. In addition, this approach provides data that are generally amenable to analysis by ASELL participants who may have little experience or training in education-related research, whilst still providing data which are useful to the wider chemistry and science education community. Education research has conclusively demonstrated the importance of student engagement, and students choose to engage based on their perceptions. If students find an experience boring and perceive that they did not learn anything by undertaking it, then it is unlikely that they will have engaged sufficiently for that perception to be in error. Whilst it is likely that students will, at times, have a positive perception of the amount they have learned which is objectively unjustified, it remains the case that investigating perception provides valuable insights into students' learning and their experiences of learning activities.

Stage Three – Peer Review and Journal Publication

Once the submitter has received and analysed the student feedback data, they will then be in a position to complete the Educational Template and prepare a submission for inclusion on the ASELL database. Complete submissions are then sent for peer review. Submitters receive reports from three referees – one of the referees will be a student who has participated in a previous ASELL workshop, one will be a member of the academic staff of a university, and one will be a member of the ASELL Management Team (comprising the Directors and the Associate Director). Communication with the submitter is carried out by a member of the ASELL Management Team other than the one who has refereed the complete submission. The submission is evaluated on both scientific and educational grounds, using the peer review criteria. Normal editorial processes are followed, in that the submitter has the opportunity to respond to the comments of the referees, but the final editorial decision rests with ASELL. Acceptance of the submission leads to the inclusion of the experiment in the ASELL database as an ASELL experiment, where details of the experiment, the Educational Template, and supporting documents for the experiment (e.g. student notes, technical notes, risk assessments, etc) are available. If the submitter chooses to publish a full journal paper (in which case the manuscript must also contain discussion of the educational analysis of the experiment) then acceptance for publication on the website (as described above) leads to automatic acceptance for journal publication with the manuscript usually subject to minor editing only. Submitters will be asked to indicate their preferred journal for publication as ASELL has agreements for publication of validated chemistry experiments with two journals – the *Australian Journal of Education in Chemistry* (published in Australia by the Royal Australian Chemical Institute) and *Chemistry Education Research and Practice* (published online by the Royal Society of Chemistry). Journals for publications in the areas of physics and biology education are currently being negotiated.

The 1st ASELL Experimental Workshop – The University of Adelaide, April 2010

At this workshop 39 experiments were submitted for evaluation in parallel sessions across the three disciplines, biology, chemistry (including 2 biochemistry experiments) and physics. Testing of these experiments was completed over a four day period by a team of 42 academics and 41 students. In addition, a special 2-day workshop was run for Deans, Associate Deans and/or their representatives (13 delegates). Although this is the second ASELL workshop the Deans have been invited to, it is the first workshop where there has been such a significant representation. Table 2a provides a summary of the delegates who represented 15 different institutions. Table 2b shows the number and some of the types of experiments tested at each workshop.

Delegates were invited to the workshop as teams (1 academic and 1 student) and paid a team registration fee. The Deans of Science at each of the participating institutions agreed to provide financial support for a team from each of the three disciplines at their institution to attend the workshop. Thus, the workshop was self funded and did not rely on external funding to run, which was the case in for past A(P)CELL workshops.

Table 2: (a) Summary of the delegates who attended the Adelaide ASELL Science Workshop and (b) Number of experiments and some of the types of activities tested at the ASELL Workshop (reproduced from Pyke et al., 2010)

(a)	Biology	Chemistry	Physics	Total
Academics	12	16	14	42
Students	12	12	14	41
Deans	5	6	2	13
Directors	1	4	1	6
Total	30	41	31	**102**

(b)	Biology	Chemistry	Physics
Total	12	13	14
Types of labs	Dissection	Titration	Pendulum
	Botany	Synthesis	Radioactivity
	Enzymes	Analytical chem	Optics
	Genetics	Biochemistry	Oscilloscope

The workshop was organised following the procedure shown in Figure 2. Delegates were sent an invitation to submit an experiment and attend the workshop 5 months prior to the workshop. Academic staff delegates submitted an Expression of Interest to the project manager for the experiment they wanted to have evaluated. After consideration of the types of experiments submitted, academics were notified whether their experiment was accepted for evaluation at the workshop. Following the acceptance notification, academics were required to submit all the necessary documentation such as student notes, demonstrator notes, technical notes, and hazard/risk assessments for the experiment to the project manager, who then passed the technical notes, experiment notes and risk assessments on to the technical staff and PhD students who were employed to set up the workshop. The PhD students who set up the experiments acted as technical staff throughout the workshop.

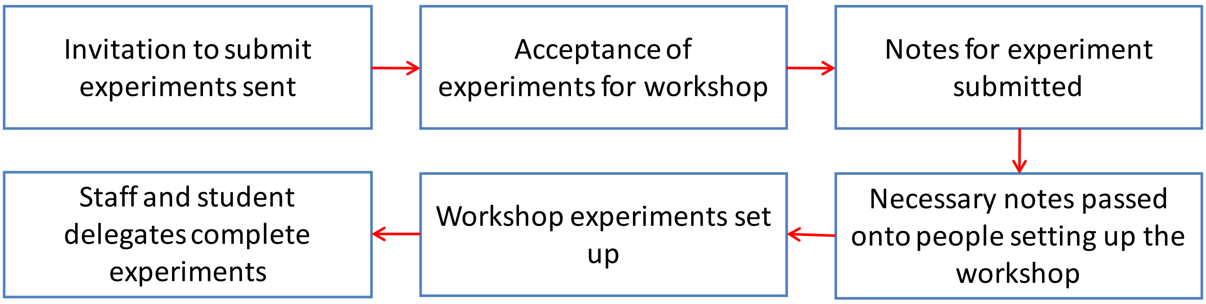

Figure 2: The process undertaken to set up the ASELL Science Workshop held at the University of Adelaide (reproduced from Pyke et al., 2010)

Structure of the workshop

The workshop itself had a very full schedule (see Table 3). A flowchart of a typical day's events is illustrated schematically by the cycle of photographs in Figure 3. Each day involved morning discussion sessions focussing on the educational aspects of laboratory work where delegates were guided through an educational analysis of their submitted experiment (this provided scaffolding for completion of the ASELL Educational Template). Morning and afternoon laboratory sessions (each 3 hours long) were separated by a communal discipline lunch break. The Deans started participating on the second day of experimental work and participated in the same activities as the other delegates.

Table 3: Schedule of the workshop

	9am-10am	10am-1pm	1pm-2pm	2pm-5pm		6pm-7pm	7pm-late
Tuesday 6 April		Registration	Lunch	ASELL Discussion		Welcome Mixer	
Wednesday 7 April	ASELL Discussion	Lab Session	Lunch	Lab Session		Feedback Session	Dinner
Thursday 8 April	Deans Discussion	Lab Session	Lunch	Lab Session		Feedback Session	Workshop Banquet
Friday 9 April	Deans Discussion	ASELL Discussion	Lunch	Deans Discussion			

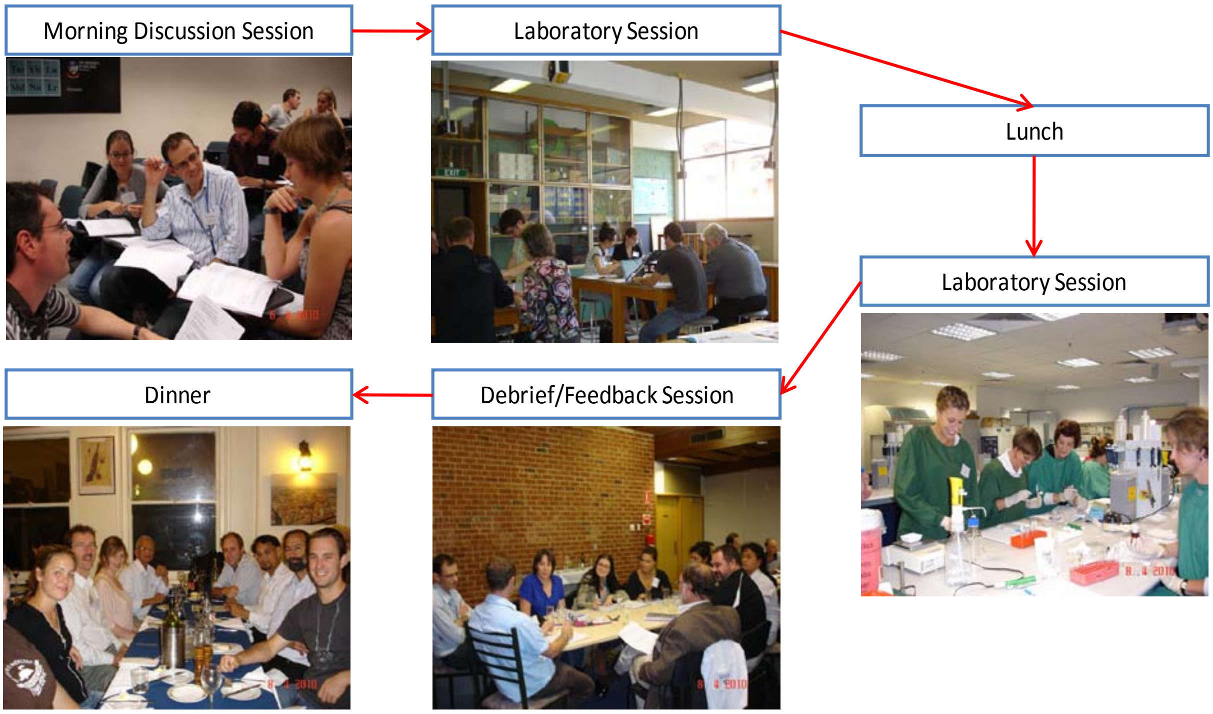

Figure 3: Flowchart of a typical day's events at the ASELL Science Workshop (reproduced from Pyke et al., 2010)

In the laboratory sessions, academic staff delegates took on the role of a student in testing the experiments, with the exception that the academic that submitted the experiment acted as the demonstrator. All delegates (academic staff and students) were assigned to work in pairs and with different people in each laboratory session, fostering networking opportunities and furthering ASELL's community of practice aims. The pairs that were assigned consisted of student + student, academic + academic, and academic + student. The Deans were treated as academic staff delegates and were also assigned a partner. Often, delegates, especially academics and the Deans, were required to move beyond their comfort zone by undertaking experiments outside their area of expertise. This was important in allowing academics to experience what students feel when confronted with a new experiment in an unfamiliar environment.

An important part of each day was the debrief and discussion sessions. Before the experience of the day's activities was lost, delegates were asked to critically evaluate the experiments they undertook that day in a discussion forum with the submitter, with notes taken, and anonymously via a written survey. Delegates approached these sessions very seriously, with many discussions continuing over dinner, a time that was supposed to allow people to relax after a hard day's work. One participant commented by saying:

> *"It was good to have discussion session in the evening to allow everyone to think about the experiments and potential improvements. It also allowed me to discuss certain experiments with people who had not actually done those experiments before, which at times led to novel ideas being developed".*

Challenges in setting up the experiments

Many challenges arose while setting up for the workshop. Firstly, it was difficult to determine in which discipline workshop 2 biochemistry experiments would be assigned. Being an interdisciplinary subject, with aspects of the experiment from chemistry and biology, the decision was left to the submitters of the experiments. In both cases, the chemistry workshop was chosen.

Secondly, it was difficult to find technical staff and students who were available for a fixed period prior to the workshop to set up the experiments and act as technical staff throughout the workshop. Fortunately, a very competent and efficient crew were found. Table 4 shows the number of people who were required to set up the experiments for each discipline.

Table 4: The support staff required for each discipline

	Biology	Chemistry	Physics	Total
Tech staff	2	2	1	**5**
Student helpers	3	3	3	**9**
Academics	1	1	1	**3**
Total	**6**	**6**	**5**	**17**

Using the notes provided by the submitters, the experiments for the chemistry and biology workshops were set up in the corresponding laboratories at the University of Adelaide. In general, most of the setup commenced about 2 weeks before the workshop. However, due to some aspects of the biology experiments, preparations started as early as a month before the workshop. Tasks that required more time to prepare included:

- growing roots for particular experiments
- growing bacteria for microscope experiments
- obtaining plants for experiments that were run interstate that could not be taken into South Australia due to quarantine restrictions
- obtaining specimens for a brain dissection experiment

Academics who submitted physics experiments were asked to send or bring their own equipment, except for common equipment provided on a list by the host institution. Thus, one of the major tasks for people setting up the physics workshop was to coordinate the receiving of equipment before the workshop and returning the equipment after the workshop. Furthermore, due to many of the physics experiments using electronic and specialised equipment such as lasers and optics equipment, precise set up was very important.

Equipment for biology and chemistry activities was provided by the host institution. However, not all of the experimental activities were easy to set up and some experiments required assistance from other disciplines. For example, the two biochemistry experiments that were run at the chemistry workshop required equipment that was provided from biology. If there were any materials that could not be provided by the host institution, the submitters were asked to either send these beforehand or bring it with them if it was able to be transported easily. However, this was kept to a minimum.

Fortunately, in most cases, enough laboratory space was available for the majority of experiments to be set up the day before they were due to be run, allowing for the workshop to run smoothly. The only concern was ensuring the delegates for the physics workshop were in the correct laboratory as 6 small laboratories spread over 3 floors were used.

Evaluation Methods

Substantial efforts were made to collect research data during the workshop. Data on the workshop were collected in several ways. Delegates were asked to complete surveys for each experiment they tested – one relating to the actual experiment and one relating to the Educational Template for the experiment. The surveys, together with the discussion from the debrief session, provided feedback on each experiment to the submitter. The survey results for the each submitted experiment were returned to the submitter before leaving the workshop, a desirable practice that had not been implemented at previous A(P)CELL workshops. This allowed the submitters to make immediate changes when they returned home, rather than having to wait for the analysis to be complete. In addition, a survey was also conducted at the conclusion of the workshop, which focussed on the delegates' experiences of the workshop and examined the workshop process itself, including its strengths and weaknesses. The surveys were designed to provide a mix of quantitative and qualitative data, allowing for a deeper understanding to be achieved through methodological triangulation (Denzin & Lincoln, 1994). Triangulation allows data interpretation which better reflects the actual experiences of delegates than would otherwise be possible (Sidell, 1993).

The ASELL Workshop Evaluation consisted of sixteen 5-point Likert scale questions and four open-ended questions. For the Likert scale questions, where appropriate, the distribution of responses were compared using non-parametric χ^2 testing, and also by assigning each response a value (+2 = strongly agree to -2 = strongly disagree; the central point on the scale was 0 = neutral) and using independent samples t-tests to compare means.

Delegate responses to the open-ended questions were subject to a content analysis, where each comment was coded into one of six broad categories, following the same procedure used in a previous report of an earlier ACELL workshop (Buntine, et al., 2007; Read, et al., 2006). Content analysis is defined by Krippendorff (1980) as a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit coding rules. It is a methodology used in the social sciences for studying the content of communication (Babbie, 2010; Mason, 2002; Miles & Huberman, 1994; Silverman, 2005). Almost all comments could be allocated to one of the 6 categories. Once categorised, all comments were classified as either 'positive' or 'negative'. Table 5 shows the coding categories, as well as the number of positive and negative delegate responses for each category.

Table 5: Broad categories used in content analysis of delegate responses of open-ended questions

	Academic Comments			Student Comments			
Category/Code	**Positive**	**Negative**	**Total**	**Positive**	**Negative**	**Total**	**Grand Total**
Delegate Interactions	37	3	40	25	3	28	68
Educational Aspects	20	2	22	19	2	21	43
Workshop Design	38	46	84	18	40	58	142
Project Design	5	12	17	3	8	11	28
Project Impact	19	0	19	9	0	9	28
Miscellaneous	5	0	5	2	0	2	7
Total comments	124	63	187	76	53	129	316

The following *Results and Discussion* section is organised according to each of the coding categories shown in Table 5.

Results and Discussion

Delegate Interaction (DI)

Academic and student delegates were each asked 2 Likert scale questions from the DI category. These questions were designed to determine whether delegates' perceptions of each other had changed due to participation in the workshop. It was found that a greater proportion of students thought that the workshop increased their awareness of the commitment of academic staff to improve laboratory learning (see Figure 4a).

Amongst the academics, there was agreement that participating in the workshop had reminded them of "what it's actually like to be a student" (Figure 4b) because working as a student on an experiment is something that many academics had not done in a long time. From a constructivist standpoint (Bodner, 1986; Palinscar, 1998), students learn best from student-centred activities. However, it is often difficult for academics to design such activities if they have trouble 'placing themselves in students' shoes'. The ASELL process provides a useful means for academics to gain insight into students' perspectives, thereby facilitating the design of student-centred laboratory exercises.

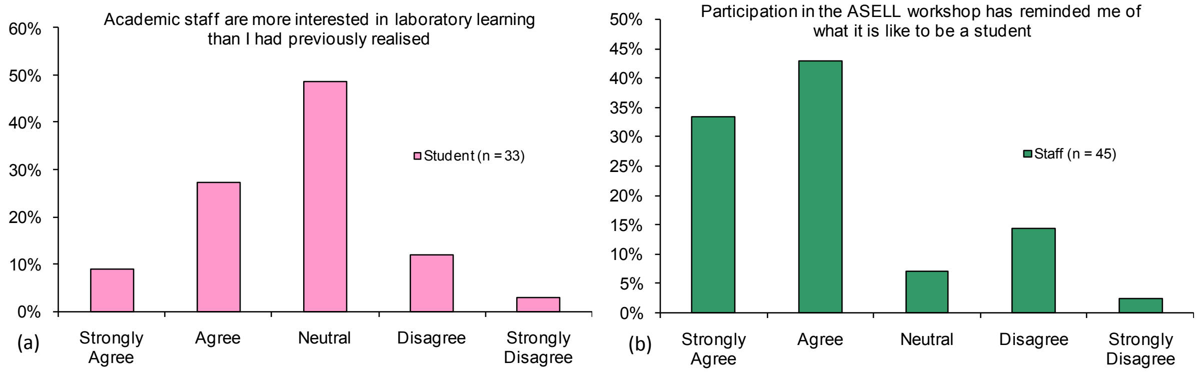

Figure 4: Delegate responses to Likert scale items on delegate interactions

Delegate responses to the open-ended questions coded to the DI category covered themes such as networking and discussions, perceptions of one another, and feedback and collaboration. The positive comments of the delegates are consistent with the quantitative data presented in Figure 4. A χ^2 analysis was used to determine whether the distribution of positive responses for of the participants was the same as the distribution of negative responses. As shown in Table 5, there are significantly more positive responses than negative responses by both academics and students [$\chi^2 = 46.2$, $df = 1$, $p = 1.08 \times 10^{-11}$]. Academics and students were able to gain insight into the other's perspective. Some students were particularly surprised at

> *"the extent to which staff strive to make labs valuable learning experiences for students. Much more time goes into them than [they] thought as a student and the staff are really invested in improving them".*

and

> *"the effort my professor and academic staff put into lab based learning and what issues surround it"*

Academics and students worked together as equals and one student commented by saying

> *"I was surprised by how welcomed I was as an undergrad student. I felt that my opinions and comments were valued. Ultimately, the experiments being tested are for students like [them] but did not expect to be treated so well and valued so highly. I was surprised and pleased to be able to mingle with superiors, even deans of science from their universities"*

In the evenings the delegates, who were not grouped by discipline, enjoyed some downtime over dinner therefore allowing for cross discipline interaction. These were the key times people from different disciplines could interact with each other due to the full workshop schedule. Although this is the first time a workshop of this nature has been run, delegates even felt they wanted:

> *"…more interaction across disciplines and would have like to see some of the other experiments that were run. Perhaps even a session akin to a poster session where one could view and discuss a range of experiments" (academic)*

and

> "*cross over between disciplines (e.g. Bio students do a physics prac) to more closely simulate undergrad students and the associated lack of background knowledge" (student)*

This was echoed in a range of similar responses:

> *"It might be useful to have cross-disciplinary interaction. Sharing a room with someone from physics led to some useful discussions (student)"*

and

> *"I was hoping to have had the chance to participate in a different discipline's experiment (student)"*

The workshop also afforded many networking opportunities, which are of benefit to academics as they were exposed to new ideas they could take back to their home institution. One academic said they valued the

> *"feedback provided for the experiment I was running - it will be very useful in re-designing the practical and the advice given provided insights that we likely would not have thought of"*

while another academic said that they enjoyed

> *"discussing with other academics at other unis how their labs work. It enabled me to see the similarity and differences and subsequent difficulties encountered with different methods".*

There was also particular mention of "*schmoozing with the deans*", which is something many academics and students do not often have an opportunity to do.

The networking opportunity was also a benefit to students. One student said

> *"as an undergrad student, it was fantastic to be able to mingle with post-grads and academic staff.*

It was nice to be treated as a 'staff' member and it was good to know that student's opinions were taken seriously. I felt I was provided with an excellent avenue to express opinions and feedback"

While another said that

"meeting academics and doing experiments with them helps me realise their views".

As a consequence of running the workshop, a community of practice was developed for those responsible for laboratory learning. A delegate valued

"the gathering of enthusiastic scientists/educationalists to work out ways of providing a better understanding of scientific discipline to students and motivating their interest"

This satisfies Aim 2 of the project.

Educational Aspects (EA)

According to the workshop evaluation, both academics and students agreed that participation in the workshop led to an improvement in their understanding of educational issues (Figure 5). An independent samples t-test was used to determine whether the mean of the academics' responses was the same as the students' responses on the -2 to +2 scale. It was found that the mean response of students of +1.52 ($\sigma = 0.57$) was slightly more positive than the mean academic response of +1.33 ($\sigma = 0.76$), however the difference was not statistically significant [$t = 1.21$, df = 77, $p = 0.231$]. This is not surprising as the workshop allowed delegates to think about educational issues uninterrupted and facilitated by the immersive nature of the workshop design.

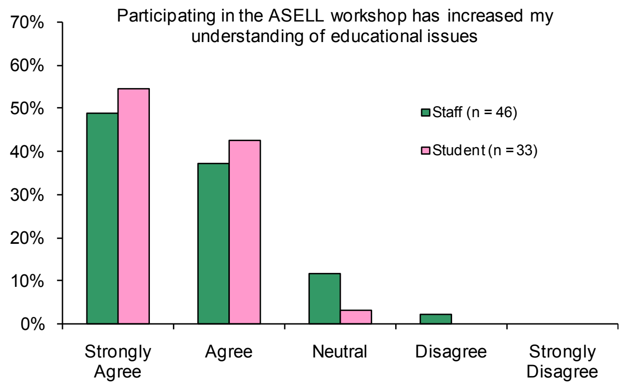

Figure 5: Delegate responses to Likert scale items on Delegate Interactions

Delegate responses to the open-ended questions coded to the EA category covered themes such as delegate educational awareness, and quality/effectiveness of laboratory exercises. Similar to the DI category, a χ^2 analysis was used to determine whether the distribution of positive responses for of the participants was the same as the distribution of negative responses. There were significantly more positive responses than negative responses for both academics and students [$\chi^2 = 29.9$, $df = 1$, $p = 4.44 \times 10^{-8}$]. Examples of positive comments include:

Academic: *"Deeper understanding of role and purpose of labs"*

Academic: *"An appreciation of more complex aspects of laboratory education"*

Academic: *"Introduction to educational methods – something I will do in a more formal way in future (and understand better conversations amongst other academics in this field)"*

Academic: *"Knowing what makes a good lab helps you design and demonstrate it more effectively"*

Student: *"Acknowledging that the practical experience is vitally important to students' learning* *and satisfaction levels and finding ways to evaluate and improve practicals"*

Student: *"How student opinions of what makes a good practical differ from staff opinions and my own (postgrad/demonstrator) opinion"*

Student: *"The uniformity of troubles various institutions had with their labs and the overwhelming tendency for them to not have been revised in a long time"*

Student: *"...the design of experiments takes into consideration a wider range of areas than I had previously thought"*

Figure 6 presents the Likert scale items that only academics responded to. These items concerning educational aspects were posed in the workshop evaluation survey because they have been highlighted as learning outcome areas for consideration in the ASELL Educational Template.

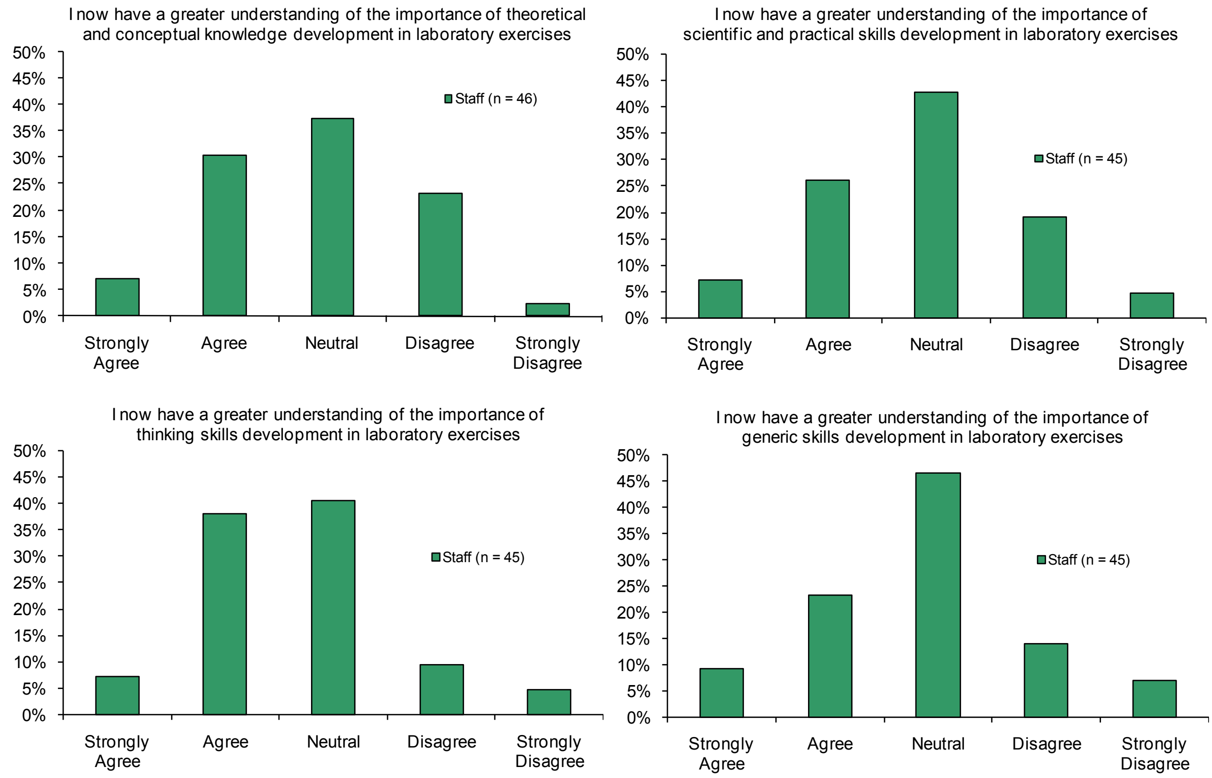

Figure 6: Academic responses to Likert scale items on Educational Aspects included in the ASELL Workshop Evaluation Survey

In general, a greater percentage of academics agreed or strongly agreed to the items compared with those who disagreed or strongly disagreed. Surprisingly, these differences were not a large as expected. A suggested reason is that some academics who attended the 2010 workshop had also attended a previous A(P)CELL/ASELL workshop or had previously been exposed to ASELL principles. Fourteen academics (31 %) reported that they had already attended an ASELL seminar previously, thereby receiving some professional development on laboratory learning in the past and contributing to the negative responses. In other words, an academic response of 'disagree' or 'strongly disagree' does not necessarily imply that academics do not have an understanding of educational aspects of laboratory learning. Rather, they might already have a good understanding from attending other ASELL events and they did not gain a **greater** understanding of such issues. Those new to ASELL did value *"the professional development and being made to think about educational theory* *with respect to labs".*

Workshop Design (WD)

Academics and students results indicated a positive response to the two Likert scale items concerning the structure and design of the workshop (see Figure 7). For the question "The ASELL workshop offers a useful means to improve students' learning in laboratory exercises", the mean academic response was 1.37 ($\sigma = 0.49$) and the mean student response was 1.45 ($\sigma = 0.56$) on the +2 to -2 scale. A χ^2 analysis used to determine whether the distribution of academics' responses was the same as the distribution of students' responses found that no statistically significant difference existed between the two groups [$\chi^2 = 1.31$, $df = 1$, $p = 0.251$]. Similarly, for the question "Participation in the ASELL workshop has been a valuable experience for me" the mean academic response was 1.47 ($\sigma = 0.55$) and the mean student response was 1.24 ($\sigma = 0.83$). Again, no significant difference was found for the two groups after a χ^2 analysis was performed on the distribution of academic and student responses [$\chi^2 = 207$, $df = 1$, p = 0.649], indicating that the workshop design was beneficial for both academics and students.

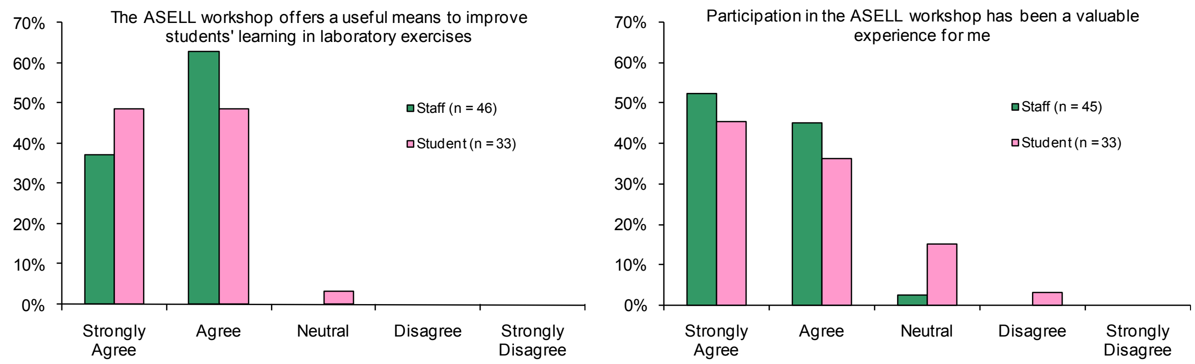

Figure 7: Delegate responses to the Likert scale items on Workshop Design

Responses to the open-ended questions include comments covering themes such as format, timing, venue and facilities, delegate laboratory exercise allocations, and laboratory exercise time allocations. Both the students and the academics answered significantly more negatively than positively [$\chi^2 = 9.11$, $df = 1$, $p = 2.55\times 10^{-3}$] about the workshop design. There was no significant difference between the response pattern of the academics and the students [$\chi^2 = 2.90$, $df = 1$, $p = 0.0887$]. Although there were more negative comments, the comments provided constructive criticism to help improve the workshop. They also demonstrated that delegates showed a high level of engagement with the process. For example, many delegates had comments like

> *"More time[needed] to discuss pracs at end of day. 15 mins is too short. At no time did we finish within the 15 mins"*
> *"More discussion time allowed after the experiments completion (i.e. Formal group discussion)"*
> *"The review (feedback) session at the end of each day need to be extended by 30 mins or so. Interesting and useful discussions were often truncated"*

Other comments about timing related to the length of time allocated for experiments. It seems that 3 hours was too much time for physics experiments as demonstrated by the following comments:

> *"Time management - experiment didn't take anywhere near the allocated time for physics. I think it would have been more useful to have shorter (2 hour) slots then discuss the experiment for*

longer (~1hr) immediately after then would wouldn't have to hang around until 7pm each night"

"For physics experiments often 3 hours was not necessary"

These comments can be taken into consideration when organising the next ASELL workshop.

Throughout the workshop delegates were required to complete a number of surveys that provided feedback to academics who submitted experiments. Anecdotal comments made after the first day of the workshop and also found in the workshop evaluation survey were suggestions like

"Survey forms to be available earlier in the lab session" or

"Let participant fill in the comment on the educational template survey immediately after the lab, by the evening we are too tired"

Again these comments demonstrated a high level of engagement and these criticisms were constructive.

After addressing the need to distribute the surveys during the laboratory session and before the debrief sessions, some positive comments resulted such as:

"extra time to fill out the evening session form - this worked well on day 2 when we got them during the lab session"

"giving us the prac template and survey prior to the debrief session was a much better method than trying to squeeze both things into 30 mins (it is one of the most important parts of the workshop)".

Other positive comments were mainly concerned with issues such as

"seeing the sorts of pracs being run at other institutions. Some were very similar but I was still able to get new ideas or some new motivation"

"experiencing labs designed by other institutions, what worked and what didn't work when doing the experiments".

As mentioned earlier, one of the key objectives of the workshop was to build a community of practice. These comments demonstrate the delegates appreciated learning from each other and it was evident as the workshop progressed that such a community was established.

Project Design (PD) and Project Impact (PI)

Although these categories are not directly related to the workshop design, delegates at the workshop were very positive about the impact the ASELL project can have on improving learning in the laboratory. Many academics thought that

"seeing how other universities design their lab experiments gave [them] many ideas and insights into what [they] can re-evaluate and improve [their] labs"

and that

"It is an excellent experience and I want to improve my experiments at my institution after getting feedback"

Other academics commented on the ASELL process and thought that

"the process of evaluating an experiment was valuable. This kind of process (with third party evaluators) is not done in our university"

while another said

"the whole process is excellent. It seems to really help academics to relive the students experience momentarily and gain valuable insight for improvements to their teaching and learning practices"

Student comments on the ASELL process and their experience of it was also very important. Their comments were all very positive. Some examples include:

"Overall the workshop was hugely valuable in so many ways for an undergrad student. I had fun, met new people and learnt a lot in the process. In this regard, I could not have asked for more!"

"Opening my mind up to what is out there. Now I have a different appreciation for lab workshops - realise how important they are"

"[The process is] hugely valuable. Changed my perspective on the education process as a student"

"Exposure to new methods of thinking about pracs"

Most of the comments on project design concerned the ASELL Educational Template. Although there were significantly more negative responses than positive ones when looking at the open ended questions, the quantitative data shows that academics see the value in using the Educational Template with 77 % intending to use it to evaluate other experiments and 81 % intending to use it when designing new laboratory exercises (see Figure 8). A session during the workshop was dedicated to helping the delegates complete their Educational Template and scaffold them through the process. However, more time may have been needed to develop confidence in using the Educational Template. Examples of the criticisms of the Educational Template are:

"the educational template analysis can be very complicated and difficult to fill out, as opposed to critiquing the actual lab which is quite easy" (academic)

"I didn't really follow the educational template evaluation for, what was the point of this" (student)

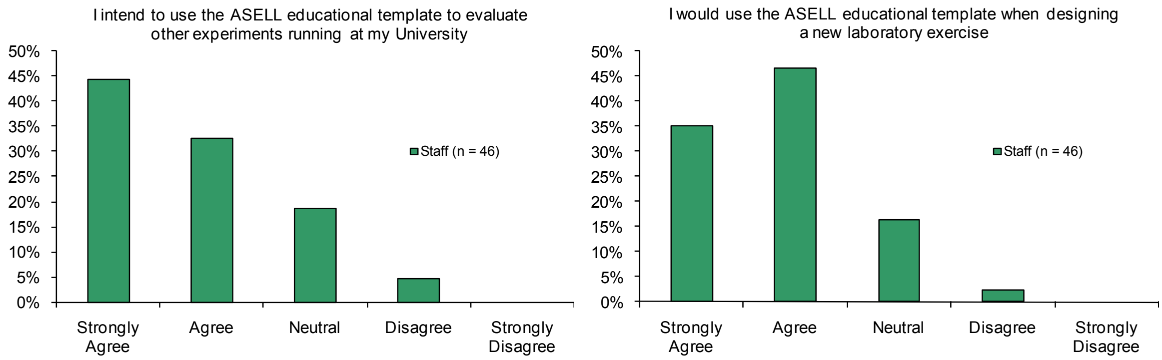

Figure 8: Academic responses to Likert Scale items concerning the ASELL Educational Template

Impact of the ASELL Workshop on the Host Institution and Other Communities

Hosting the workshop raised the profile of not only 'what makes a good experiment' but also the similarities of these factors across what had previously been considered to be a lack of any common ground amongst the disciplines. In concert with other curriculum renewal activities currently in progress, the workshop provided increased opportunity for development of a more holistic approach to curriculum design, particularly in the core Level 1 discipline areas, with a focus on improving the student experience within the laboratory programs.

The first national ASELL workshop was also a driving force for local discipline communities to establish. A group of academics from Victoria have set-up their own ASELL biology branch and will run an ASELL Biology local workshop in June 2011. International communities have also been established. Funding obtained from the Philippines Commission on Higher Education has allowed the adoption of ASELL principles across 46 institutions from October 2010.

Comparison with previous ACELL workshops

It seems clear that the ASELL workshop had many benefits for all delegates involved. One question that was posed afterwards was how the first ASELL Workshop held in April 2010 compared with other ACELL workshops held in the past. If there were differences, it would have implications on the future direction of the project. So, comparisons were made between delegates' responses between the Sydney 2006 (ACELL), Sydney 2009 (ACELL) and April 2010 (ASELL) workshops. The Sydney 2006 and 2009 workshops were chosen because they are the most recent workshops of similar size and duration that have been run.

When examining the student responses across the three workshops using both one-way ANOVA and χ^2 analyses for two items from workshop evaluation specific to students, statistically significant differences were found. For example, different distributions of responses arose for the statement "Laboratory exercises are intended to teach more than I had previously realised" with a larger number of participants indicating that they strongly agreed or agreed with the statement [$F_{2,71} = 14.1$, $p = 6.90 \times 10^{-6}$, $\chi^2 = 21.7$, $df = 4$, $p = 2.29 \times 10^{-4}$] (see Figure 9a). A suggested reason for this difference is the demographic variations of the students who attended the workshop over the years (see Figure 9b). The Sydney 2006 workshop consisted of primarily undergraduate students with very few postgraduate/Honours students. The Sydney 2009 workshop had more postgraduate/Honours students with slightly fewer undergraduate students. However, the April 2010 workshop consisted mainly of postgraduate/Honours students with very few undergraduate students. χ^2 analyses confirmed that a statistically significant difference in student population existed [$\chi^2 = 15.92$, $df = 4$, $p = 0.0031$]. Postgraduate students tend to be involved with some teaching activities (e.g. demonstrating/tutoring) while completing their studies and such experience would likely influence their perspectives on the amount of effort that is required to develop quality learning activities. Therefore it is not surprising that student responses would be different across the years. This result is consistent for the second question specific to students. Further research about the student demographics is required to adequately conclude that this is the sole reason for the observed difference.

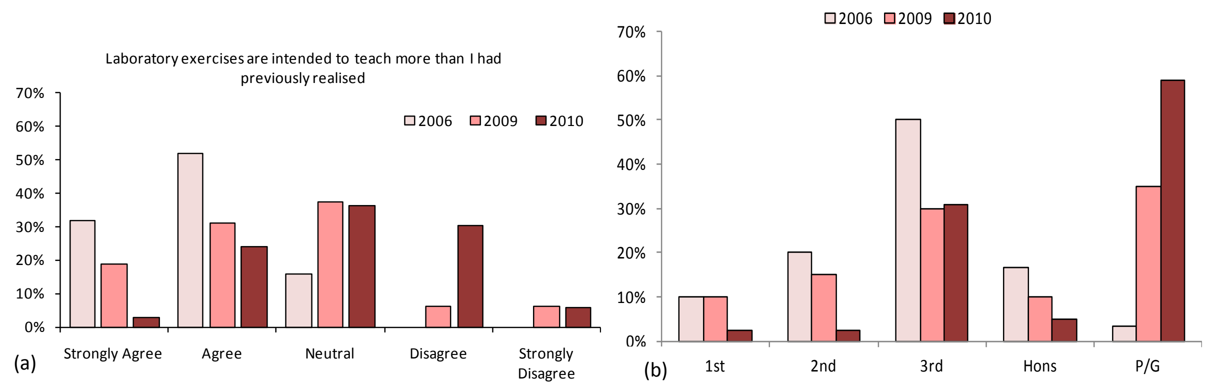

Figure 9: Comparison of (a) student responses to a question from the workshop evaluation and (b) distribution of student population at past workshops

In contrast, no significant differences were found for academics' responses across the workshops, e.g. "I would use the ASELL educational template when designing a new laboratory exercise" [$F_{2,85} = 1.84$, $p = 0.166$, $\chi^2 = 4.08$, $df = 4$, $p = 0.395$] (See Figure 10). This may be surprising since the demographics of the academics, was different across the workshops. The 2006 and 2009 workshops were chemistry workshops and only chemistry academics attended. The 2010 workshop included academics from other science disciplines. However, since significant differences were not found amongst the academics responses, it demonstrates that the ASELL workshop made a similar impact on academics regardless of their discipline.

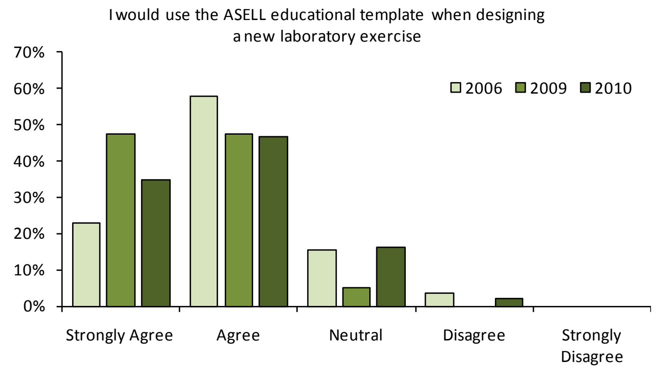

Figure 10: Comparison of academics responses to a question from the workshop evaluation

Furthermore, there were no significant differences in the percentage of positive open response questions of the delegates between each workshop [$\chi^2 = 15.8$, $df = 10$, $p = 0.105$]. However, differences were found in the percentage of negative responses between the workshops [$\chi^2 = 53.9$, $df = 8$, $p = 7.10 \times 10^{-9}$]. Generally there were a greater percentage of negative responses about the workshop design in 2009. The 2009 workshop was organised on a much shorter timeline, possibly contributing to things not going as smoothly as the other two workshops. Despite that, there were fewer negative responses concerning educational awareness, indicating that the 2009 workshop successfully addressed educational issues of laboratory learning.

Conclusion

The 1st National and Multidisciplinary ASELL Workshop held in April 2010 at the University of Adelaide was the first workshop of its kind organised by ASELL. In the past, discipline-specific workshops had been organised, in particular for chemistry. The April workshop is the first example where experiments from three science disciplines were tested at the same time, while also allowing for cross discipline interaction during free/social time. The representation of Deans at the workshop was also much greater than at any previous workshop.

Although the primary aim was the third-party testing of experiments, academics and student delegates gained benefits far beyond this aim – from professional development through to gaining insight into each other's world, operations of other universities in Australia, and meeting new people. The workshop also assisted in the development of a community of practice for those responsible for undergraduate laboratory programs. More importantly, the ASELL Workshop demonstrated that the principles that were only used in chemistry in the past are applicable to other domains, and can be applied in a joint science context. This marks the start of more cross discipline interaction and discussions about laboratory activities in the future.

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