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AUSTRALIAN LEARNING & TEACHING COUNCIL

Promoting excellence in higher education

Advancing science by enhancing learning in the laboratory (ASELL)

Final Report 2012

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http://www.asell.org/

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List of Acronyms:

ACDS = Australian Council of Deans of Science
ACELL = Advancing Chemistry by Enhancing Learning in the Laboratory
ALPE = ASELL Laboratory Program Evaluation
ALTC = Australian Learning and Teaching Council Limited
APCELL Australian Physical Chemistry Enhanced Learning Laboratory
ASELL = Advancing Science by Enhancing Learning in the Laboratory
ASLE = ASELL Student Learning Experience
L&T = Learning and Teaching
PD = Professional Development
T&L = Teaching and Learning

Executive Summary

Most researchers agree that the laboratory experience ranks as a significant 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 and improving 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, with ALTC funding, has now expanded to include those disciplines.

The launching pad for ASELL was a multidisciplinary workshop held in Adelaide in April, 2010. This workshop involved 100 academics and students, plus 13 Deans of Science (or delegates), covering the three enabling sciences of biology, chemistry and physics. Thirty-nine undergraduate experiments were trialled over the three days of the workshop. More importantly, professional development in laboratory education was developed in the 42 academic staff that attended the workshop.

Following the workshop, delegates continued to evaluate, develop and improve both individual experiments and whole laboratory programs in their home institutions, mentored by the ASELL Team. Some highlights include:

- more than 15,000 student surveys carried out by delegates during 2010/11
- 10 whole lab programs were surveyed by delegates
- 4 new ASELL-style workshops, conducted by ASELL-trained delegates were run in 2010/11
- more than 100 ASELL-tested experiments available on the website (www.asell.org)
- ASELL workshops conducted in Philippines, Ireland in 2010, and planned in the USA and Thailand for 2011
- significant improvement in student evaluation of whole laboratory programs and individual experiments measured in universities using the ASELL approach
- high profile of ASELL activities in the Australian Council of Deans of Science (ACDS)
- research project on the misconceptions of academic staff about laboratory learning completed
- significant research on student learning in the laboratory, and staff perceptions of student learning have been carried out during 2010/11
- research results have been benchmarked against staff and students in the USA.

The biggest unresolved issue for ASELL is one of sustainability in the post-ALTC funding era. ASELL will make a series of recommendations to the ACDS, but the future of the program depends, to a large part, on how the ACDS responds.

Overview of the Project

Introduction

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. ASELL is the expansion of the previous Australian Physical Chemistry Enhanced Laboratory Learning (APCELL) (Barrie, et al., 2001a, 2001b, 2001c) and the Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) projects (Buntine, et al., 2007; Jamie, et al., 2007; Read, 2006a, 2006b). A(P)CELL began in 2000 when a number of chemistry academics noticed increasingly high levels of student dissatisfaction with their undergraduate chemistry laboratory courses. 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.

Each year across 35 Australian universities, about 20,000 students undertake chemistry units (Barrie, et al., 2001a). Almost half of student 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 outcomes 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).

In response to the above challenge and being aware that many of the academics who teach science at the tertiary level are not familiar with educational research related to students' experiences in the laboratory, ASELL was intentionally designed to assist practicing scientists to improve the quality of their teaching in the laboratory environment. As ASELL advocates a student-centred view of learning, students are included at every stage and in every aspect of the evaluation of submitted experiments. This approach ensures that the students' perspective is integral to an experiment satisfying the ASELL criteria, and has proven to benefit both academic and student participants; teaching staff are reminded of the experience of being a student undertaking an unfamiliar experiment, whilst students gain insight into the educational complexities involved with laboratory work.

The project Team

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Lead institution: The University of Sydney

Institutions that have participated in the project:
Curtin University
Deakin University
Edith Cowan University
Flinders University
Griffith University
La Trobe University
Monash University
Murdoch University
Swinburne University
The University of Adelaide
The University of Melbourne
The University of Newcastle
The University of Queensland
The University of South Australia
The University of Western Australia
University of Western Sydney
University of Wollongong
Victoria University

Project Website
www.asell.org

The Project Rationale and Context

Background and project rationale

Laboratory activities have long been seen as important components of a science course (Bennett, 2000; Boud, Dunn, & Hegarty-Hazel, 1986; Hofstein & Mamlok-Naaman, 2007; Johnstone & Al-Shuaili, 2001; Psillos & Niedderer, 2002). 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).

Laboratory activities can be a popular component of science courses (Deters, 2005) because they can stimulate and motivate students to learn more about science (Hofstein & Lunetta, 1982, 2004). Indeed, most researchers agree that the laboratory experience consistently ranks highly as a contributing factor toward students' interest and attitudes to their science courses (Osbourne, Simon, & Collins, 2003). Consequently, good laboratory programs should play a major role in influencing student attitudes, learning and performance. In fact it can define a student's experience in the sciences, and if done poorly, can be a major contributing factor in causing students to disengage from the subject area. The challenge remains to provide students with laboratory programs that are relevant, engaging and offer effective learning outcomes.

In a typical Australian university science curriculum, students are expected to spend about one-third of their instructional time in laboratory work (Royal Australian Chemical Institute, 2005; Sharma, Mills, Mendez, & Pollard, 2005), so it is imperative that the opportunities afforded by this learning environment are realised. Unfortunately, educational research suggests that this potential is seldom achieved (Hegarty-Hazel, 1990; Hofstein & Lunetta, 2004; Reid & Shah, 2007). Some laboratory activities have been shown to result in working memory overload and/or cognitive disengagement (Johnstone, 1997). These activities can push students toward a 'going through the motions' approach in the laboratory (Johnstone & Al-Shuaili, 2001), leading to a perception that laboratory activities consist of simply following dull, uninteresting recipes (Del Carlo & Bodner, 2004). This environment does little to motivate students, or to support their learning.

Although educational research has been performed investigating students' experiences in the laboratory, especially with non-traditional laboratory formats (*e.g.*, inquiry, discovery, or problem-based learning), a recent review of the literature indicates that many science academics are not aware of this research (Hofstein & Lunetta, 2004). Building upon earlier success in chemistry, this project seeks to bridge the gap between educational research and practicing science educators.

The aims of the project

The ASELL project has four distinct project 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
4. to conduct (by the Directors) and enable (by the participants) research into learning and teaching in the laboratory environment.

Providing Staff Professional Development (PD)

Research suggests that effective academic staff PD, especially PD 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). Each of these objectives will be achieved through the ASELL PD model, which includes two components:

Experiential Workshops: ASELL held a 4-day workshop consisting of three parallel workshops focusing on each of the core discipline areas of biology, chemistry and physics, over the grant period. Each of the workshops focused on issues related to student experiences in the laboratory. A major focus was to ask the participants to think deeply about the role of laboratory education—in light of current research on its role and efficacy—and about what they think the laboratory provides in terms of student learning and skill development.

Action Research Projects: ASELL endorses an “every teacher a researcher” approach (Bodner, MacIsaac, & White, 1999). Academic staff took the laboratory activities they have analysed and modified during the ASELL workshops back to their home institutions and conducted small action research (Hunter, 2007) projects about their implementation. Staff used the results of their action research studies to further improve the activities. Revised activities will be posted on a public access website, allowing them to be shared with other institutions and academics. Staff will then have the option of performing an educational analysis of the revised activities for publication in a science education journal. The editorial board of the *International Journal of Innovation in Science and Mathematics Education* has agreed, in principle, to publishing ASELL-based papers.

Establishing Communities of Practice in Science Education

Wenger (2007) argues for three main characteristics that are shared by communities of practice: (*i*) a common domain of expertise; (*ii*) the existence of interactions among members; and (*iii*) the development of a shared repertoire of resources. ACELL communities of practice demonstrate clearly all three of these characteristics: chemistry education as the common domain, shared interaction through workshops and RACI Chemical Education Conferences, and shared resources through the website.

It is anticipated that academics who participate in ASELL will continue to build new communities of practice of biologists and physicists who are learning about educational issues related to student experiences in the laboratory, undertaking action research in order to improve laboratory learning, communicating the results of their studies through conference presentations, and publishing in science education journals. The project Directors will support continued contact among the members of the community by providing updates about the progress of workshop-tested laboratory activities to all participants through the ASELL website, by asking workshop participants to anonymously review each other's revised laboratory activities and manuscripts, by inviting participants to share their workshop and action research experiences in symposia at science education conferences, and by inviting enthusiastic academic participants to assist with the delivery of the subsequent workshops. The project Directors will also share project findings with the larger science education community at science education conferences.

Embedding into Faculty Practice via Science Discipline Network

An essential component to achieve long-term sustainability for this project is to effectively embed ASELL practice at each participating institution. ACELL started as a "bottom-up" network, *i.e.* a network that started with recognition of a problem by academics at the coalface of laboratory teaching, and it developed spontaneously into a collegial community of practice. ASELL must remain as a bottom-up network to achieve the professional development and community of practice objectives described above. However, we recognise there must also be a "top-down" leadership component to provide recognition of these PD activities, to fund and coordinate the activities, and to lead the drive into regular faculty practice. This is what has been lacking in the ACELL methodology, and which kept ACELL as a domain of the "initiated few", rather than supported its uptake across the broad spectrum of university science.

The national scope of ASELL, coupled with the diversity of teaching and leadership structures within Australian faculties of science makes a "distributed leadership" model appropriate (Spillane, Halverson, & Diamond, 2004). The Deans of Science need to be the "titular" leaders as they carry budgetary and line management responsibility. However, on a day-to-day basis, the Associate Deans (Learning & Teaching) are well placed to be the "contextual" leaders to achieve this goal. In this model there are three key leadership aspects for Associate Deans:

1. to act as liaison between the ASELL Board, Discipline Team Leaders and academic staff and students within their home institutions
2. to act as coordinators of interaction between academic staff and students in different disciplines within their home institutions
3. to promote interactions between academic staff and students in different disciplines between institutions.

Distributed leadership also has its critics, with concerns expressed about the lack of evidence that distributed leadership models have achieved their stated outcomes and that lack of cohesion negatively impacts the outcomes (Hartley, 2007).

Concerns such as these have been addressed in this project by the role of the ACDS. At each annual ACDS meeting, the ASELL Directorate has liaised with the Council to review progress against institutional goals. The Council provided feedback to the ASELL Directorate on future directions and to the Network of Associate Deans (L&T), which was established by the ACDS in 2008.

Research Goals

In addition to the action research projects carried out by individual participants the project directors collected and inductively examined many types of data throughout the project. The research goals are to explore how to best achieve student engagement in laboratory activities, and to elucidate what factors determine such engagement. We examined data from a large number of laboratory activities in many universities, across the three core disciplines and each of the three undergraduate years of a science degree. Such research will inform the development of future laboratory activities through ASELL workshops and the educational criteria used by ASELL to determine which laboratory exercises are included in the database.

The directors also examined the effects of workshop participation on academic staff and students. The goal is to continuously optimise the PD experience, and to provide concrete evidence of the effects of such PD. Before a workshop, all participants will be surveyed about their previous experiences and attitudes about learning and teaching in the laboratory environment. They will also be asked to comment about what they hope to learn from the workshop. During the workshops, data collection will take several forms: (*i*) field notes of the interactions between staff and students during the workshops; (*ii*) copies of the experiment feedback forms; and (*iii*) recordings of wrap-up sessions. At the end of the workshop, all participants will be surveyed about their workshop experiences.

The Project Methodology

Ethics approval

The ethics application for the project was submitted to the Human Research Ethics Committee at The University of Sydney, which was subsequently approved (project number 12-2005/8807).

Theoretical Framework

Within the cultural context of universities, academics are encouraged to undertake scholarly inquiry into teaching and learning practices. ASELL has emerged from a quest to do so. As participant observers, we are committed to improving both student learning and our teaching practices and providing evidence of improvements in student learning for a range of purposes. The path of ASELL is best viewed through the *Interpretive Theoretical Perspective* (Crotty, 1998); exploring and reflecting upon many of the assumptions underlying the languages, interrelationships and communities within which teaching and learning in laboratories are embedded. This lens has distilled professional development and communities of practice as key elements of ASELL.

At a more technical level, the development of ASELL is captured by *Design-Based Research* as it embodies the following key characteristics (Sharma & McShane, 2008; The Design-Based Research Collective, 2003):

- the design of environments and development of theories of learning are intertwined
- development and research take place through continuous cycles
- research on design lead to relevant implications for practitioners
- research must account for how designs function in authentic settings, and
- methods document and connect the processes of enactment and outcomes of interest.

Design-based research is particularly attractive to us as scientists as it mirrors scientific research. Furthermore, it prompts us as researchers to probe the extant literature for insights and share findings through conferences and publications. This lens provides us with the scope for systematically incorporating theoretical inputs, practical outputs and connecting with outcomes of interest.

Participating academics working on experiments at the local level go through iterative strategies of planned action as an *Action Research Methodology.* They implement change to improve student learning, analyse in a systematic way the impact of the innovation and adapt it to the needs of their institution (Krockover, Adams, Eichinger, Nakhleh, & Shepardson, 2001). This lens weaves through the fabric of the project as it is the professional development empowering the individual.

Experiential Workshops

The centrepiece of the ASELL methodology is the "Experiential Workshop". It is often the first exposure of academics at the laboratory-teaching coalface to educational theory and pedagogy. It is designed so that academics "rediscover" what it is to be a student, and discover for the first time the application and relevance of educational research in their own domain. Academic staff take away with them the skills to undertake an educational analysis of their own laboratory program, and the tools to improve it.

The content, processes and format of the workshop have evolved over 10 years, and 10 prior workshops in the chemistry domain. One facet of this project was to explore how the experience and lessons in the chemistry domain translate across to biology and physics.

Pre-workshops Activities

Academics who intended participating in the ASELL Science workshop first reflected on their teaching practice and the efficacy of one of their laboratory exercises by performing a directed educational analysis of what students are supposed to achieve in the exercise, how this learning is achieved, and how this learning is monitored by both the students and the teaching team. Experience with ACELL shows that many times this educational analysis is carried out initially from a teacher-focussed perspective. The academics are also required to document the laboratory exercise in the form of instructions for laboratory technical staff, demonstrators and students.

The Workshop

Laboratory Activities: The ASELL Science Workshop followed the plan refined at previous ACELL workshops (Jamie, et al., 2007). Each day involved early morning professional development and discussion sessions focussing on a particular educational theme, with mid-morning and early-afternoon laboratory sessions, each of three hours duration and separated by a communal lunch break. In these laboratory sessions, participants took on the student role in testing experiments, with the exception that each academic spent one day demonstrating their contributed experiment. Participants were assigned to work with different people in each laboratory session – staff with staff and student with students, or staff being paired with students.

In previous workshops (Jamie, *et al.*, 2007), participants were forced to move beyond their comfort zone by undertaking some experiments in areas outside their fields of specific expertise. This applied primarily to the academic participants, since all experiments are outside the comfort zone of most students to a greater or lesser extent. It is fair to say that many highly competent research-active academics expressed no small degree of trepidation at exercising skills that they may not have used since they were themselves undergraduates. At these previous workshops, the academics commented that by doing these experiments they realised that they had forgotten what it was like to be a student and that this made it difficult for them to judge the quality and effectiveness of their own experiments from the student perspective.

Wrap-up Sessions: After cleaning and setting up for the next day, each day concluded with a debriefing session to discuss the experiments tested that day. Many of these discussions continued during dinner, providing an opportunity to interact in an informal setting. The experiment itself was reviewed, providing technical feedback. At the same session the educational analysis provided before the workshop was also critiqued. In effect, these were also professional development sessions, since feedback from previous workshops indicated very strongly that it is here that the transition from a teacher-centred to student-centred outlook to the educational aspects of laboratories activities occurs.

Findings from the ASELL Science Workshop held this year will be discussed later.

Post-Workshop Activities

Modification and Peer Review: Delegates were provided with feedback about the experiments they submitted and demonstrated at the workshop. This gave each academic the opportunity to improve the experiment using action research (Hunter, 2007) back at their home institution. ASELL provides support for the academic by providing validated educational instruments, hHuman Ethics clearance for the research, a thorough explanation of how to undertake a content analysis of qualitative student feedback, and an exposition of educational research findings in common language. In other words, ASELL embraces the “every teacher a researcher” ethos, (Bodner, et al., 1999) and provides a scaffold for the academic who is uninitiated in educational research to learn “on the fly” and to produce reliable and, ultimately, publishable teaching scholarship.

Publication: Revised laboratory activities are shared with other institutions and academics by dissemination via a public access website. Activities that satisfy a set of published ASELL criteria are formally accepted onto the database and constitute a “web publication” that is recognised by Deans of Science during promotion rounds. Furthermore, all academics are encouraged to develop their ASELL project into a refereed journal publication by performing an educational analysis through formal student surveys and feedback. Since 2001, 13 APCELL- (the physical chemistry progenitor to ACELL) and ACELL-based papers have been published in the *Australian Journal of Education in Chemistry* (Lim, 2009). Acknowledging the wider discipline base of ASELL, the editorial board of the *International Journal of Innovation in Science and Mathematics Education* has agreed, in principle, to publish ASELL-based papers.

Survey Instruments

A number of survey instruments have been used throughout the project. These instruments are freely available for use by ASELL-trained delegates in their home institutions, and training in their reliable and ethical use is provided at the workshop. They are summarised below:

- *ASELL Student Learning Experience (ASLE) Survey* – this survey evaluates the student experience of an individual laboratory learning activity
- *ASELL Laboratory Program Evaluation (ALPE) Survey* – this survey evaluates the student experience about a semester-long laboratory program

- *Staff Survey* – this survey probes academics' perceptions of what aspects of a laboratory activity they believe will correlate with what the students tell us are important via the ASLE instrument
- *Workshop ASLE* – this survey is distributed during the workshop. It is similar to the ASLE and is specifically used in the workshop environment, and
- *Workshop Evaluation* – this survey evaluates participants experience of the ASELL workshops.

Project Outcomes and Impacts

With respect to the four goals of ASELL described earlier, the following outcomes were anticipated for this project:

1. A database of educationally-validated undergraduate experiments on an open-access website (www.asell.org). Successful accomplishment of this outcome will be measured by the number of experiments posted on the site
2. Development of new instruments and evaluation of existing instruments, to better evaluate the student laboratory experience. The success of this objective will be measured by the uptake and use of the instruments by academics who have been trained by ASELL (see 3, below)
3. Professional development for about 90 academic staff through the three Experiential Workshops. Successful attainment of this outcome will be measured by the number of participants at the workshops and by evaluation of workshop survey data
4. New communities of practice in discipline laboratory education. This will be measured by involvement of ASELL participants in local and international conferences, *e.g.*, UniServe Science, Australian Institute of Physics, Royal Australian Chemical Institute, Australian Society for Biochemistry & Molecular Biology, and use of the project website
5. Use of the ACDS Network of Associate Deans (L&T) to facilitate further ASELL-style evaluation of laboratory exercises by ASELL-trained staff in their home institution, leading to collegial, internal quality assurance processes being established. The success of this outcome will be gauged by reports from Deans and Associate Deans on the promulgation of ASELL-style laboratory review within their faculties
6. Research outcomes on laboratory learning by students in chemistry, physics and biology will be measured by the conference presentations and journal articles on laboratory learning and professional development by the ASELL directors
7. Developing a sustainable strategy for the ongoing support of ASELL into the future.

The vehicle for fostering and maintaining outcomes 1-4 is the ASELL website: www.asell.org and so we start with a discussion of the website before describing our progress towards the seven anticipated outcomes above.

ASELL website

A public access website has been developed, with the URL of **www.asell.org**. Using the old ACELL website as a template, the new ASELL website has been redeveloped to include the disciplines of biology and physics (front page in Figure 1a). Our experience, also based on advice from our Advisory Committee, is that academics in different disciplines like to believe their disciplines are "different" and "special" (despite ASELL research that suggests otherwise, see below). Therefore each of the three main disciplines of biology, chemistry and physics, has its own home page on the asell.org site (see Figure 1b). Each discipline site, however, is really a mirror of the other disciplines, with simply a colour change. Users in one discipline should feel at home scanning through material in the other disciplines.

The website serves several functions:

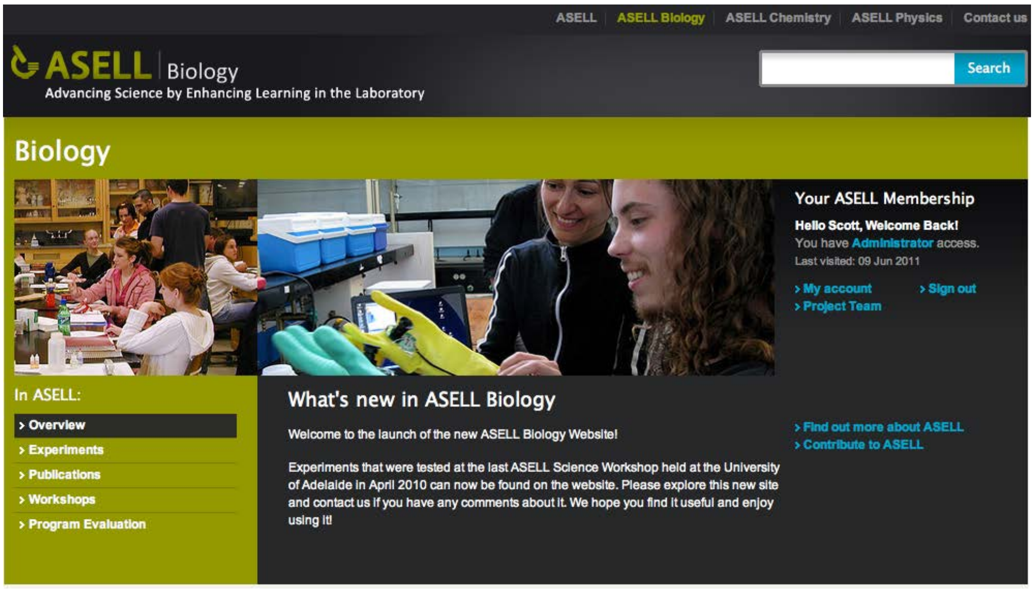
i. At the most basic, the website is a vehicle for disseminating undergraduate experiments that have been educationally assessed, at least at an ASELL workshop. Experiments are listed under each discipline, and are searchable by either a set of sub-disciplines or topics and by keyword (see Figure 1c). The users might not realise that when they search for a topic while in the, for example, biology site, that all experiments are being searched, irrespective of discipline (for example, quantum mechanics experiments might appear under either physics or chemistry). All experiments contain students notes, demonstrator notes, technical notes, OH&S notes, the ASELL Educational Template for the experiments, and any survey material that has been collected. The database is discussed further under Outcome 1, below
ii. The website is a source of writings about general principles and theories about learning science, summaries of some relevant educational research. Some of this material has been written by the ASELL Team, while other material is from the research literature. The website also provides materials that recast educational research findings into the language of scientists and that describe qualitative research methodologies, assisting science academics to engage in scholarly education-related activities. Any person who comes away from the ASELL website with an enhanced level of awareness of the complexity of laboratory learning or with practical ideas for adoption contributes to the implementation of project goals
iii. The website advertises upcoming ASELL events, for example workshops, and provides a summary of past events. This contributes to the maintenance of a community of practice.

The website is used fairly heavily. Currently, the website is hit about 16,000 times per month, by 14,000 visitors. Each month, the site is visited by 1,000 unique users. To gauge the number of visitors who engage with the site, we also monitor repeat visits and users who register with the site.

The web site content is protected to various degrees. To gain first level access to experiments on the site, a user has to register. This is an automated process and registered users can immediately gain access to all of the general information about the experiments. To gain access to demonstrator notes, worked answers and safety information, a user must send an email to the site, requesting upgrade to "academic" status. These emails are read by a member of the ASELL Directorate and the identities of the senders are verified, usually by searching for them on their school/university web pages. As of August 2011, the ASELL site has 780 registered users, of which 350 have registered since the ALTC project started. Of these, 78 users have been granted "academic" status (all since ALTC project started as we reset the academic status with the new website. More about the demographics of users can be found in the Community of Practice section below.

a)

b)



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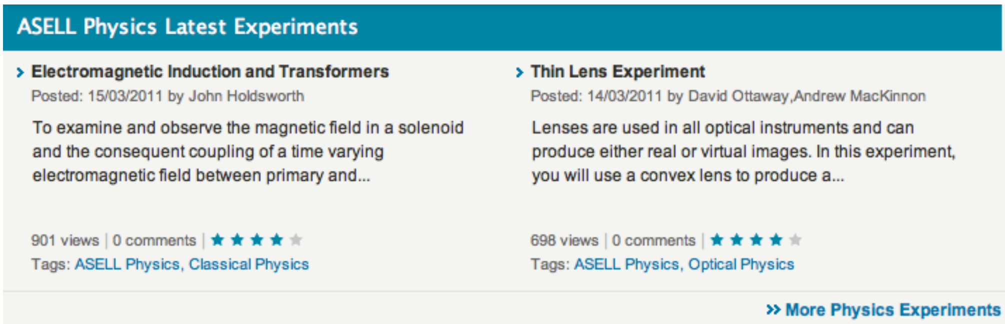


Figure 1: Snapshots of various pages from the ASELL website, including a) home page featuring Community of Practice information, b) Biology home page and c) page advertising latest Physics experiments in the database

Progress towards the seven project outcomes.

1) A database of educationally-validated undergraduate experiments on an open-access website (www.asell.org). Successful accomplishment of this outcome will be measured by the number of experiments posted on the site.

The asell.org website currently has 78 experiments – 54 from chemistry (the chemistry project pre-dates the ALTC project), 13 from physics and 10 from biology. Three more workshops were run in July 2011, and these experiments have not yet filtered through to the database. We expect to host over 100 fully tested experiments by the end of 2011, which was our milestone.

In order for an experiment to be accepted onto the ASELL web site (a web publication, see below), it must pass through a rigorous evaluation of both its chemical and educational merits. 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. 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 who might wish to adopt them. The first stage is bringing an experiment to a workshop, where it is tested both scientifically and educationally, and transferability to a new location/laboratory is checked. Surveys are collected at the workshop. At this stage, the experiment may be submitted to the website. Submitters must provide:

i) student notes
ii) demonstrator notes
iii) technical notes
iv) OH&S notes
v) educational analysis of the experiment from the workshop
vi) survey data from the workshop.

2) Development of new instruments and evaluation of existing instruments, to evaluate better the student laboratory experience. The success of this objective will be measured by the uptake and use of the instruments by academics, who have been trained by ASELL

Five instruments were employed during the course of this project.

- *ASELL Student Learning Experience (ASLE) Survey* – this survey evaluates the student experience of an individual laboratory learning activity
- *ASELL Laboratory Program Evaluation (ALPE) Survey* – this survey evaluates the student experience about a semester-long laboratory program
- *Staff Survey* – this survey probes academics' perceptions of what aspects of a laboratory activity they believe will correlate with what the students tell us are important via the ASLE instrument
- *Workshop ASLE* – this survey is distributed during the workshop. It is similar to the ASLE and is specifically used in the workshop environment, and
- *Workshop Evaluation* – this survey evaluates participants experience of the ASELL workshops.

Three of these (ALSE, Workshop ASLE, Workshop Evaluation) were brought into the project from ACELL and subject to further evaluation. Two (ALPE and staff survey) were developed during the ASELL project.

ASELL Student Learning Experience (ASLE):

This instrument forms one of the pillars of the ASELL experience for most academics. It aims to measure the student experience in a single laboratory exercise. The instrument is implemented immediately at the end of the laboratory session, while the experiment is fresh in the students' minds, but often *before* assessment is complete. The instrument does not try to measure student learning or the quality of the assessment process. The intent of the survey is summarised by the final Likert item: "*Overall, as a learning experience, I would rate this experiment as*", with a range of student responses from excellent to very poor.

This instrument has had a long evolutionary history. It was first conceived during the APCELL phase of the project (2000-2003). Then, it was a scoping instrument with a series of items with open-ended responses. The instrument was used to explore 12 experiments in a number of universities, with a couple of hundred student responses.

During the ACELL phase (2004-8) the APCELL instrument was analysed and a new instrument developed. This instrument now had two parts: 14 statements with standard A-E Likert responses, and 5 open-ended questions. Thirty-eight experiments, from 16 universities were surveyed, involving 1608 students. The instrument proved very valuable for diagnosing strengths and weaknesses in an individual experiment. The evaluation proved sufficiently novel and informative for two such analyses to be published in international journals (Read et al., 2007; Crisp et al., 2011), and we are aware of at least a couple more in preparation.

The 1608-strong dataset also provided a significant resource for further evaluation of the instrument during the ASELL (ALTC-funding) phase. We performed a Principle Component Analysis of all 1608 responses. We determined two robust factors, which we called "interest and engagement", and "assessment and learning". Two questions fell outside these factors: "time to complete the experiment" and "teamwork"; these probe two different facets of an experiment and are monitored separately. The ASELL Team, however, determined one Likert item (Item 14: "Overall experience"), to be poorly designed as the scale in the (original) ASLE(I) instrument did not have a neutral response and hence was not symmetric about the central response. In light of the extensive prior dataset, we did not take the decision to change this item lightly. A further 16 experiments (1400 students) were run under the ASLE(I) instrument, about half of which were run in parallel, and with randomly distributed (revised) ASLE(II) instruments. The responses to the new item 14 have now been carefully benchmarked against the more than 3000 responses from the original instrument.

The new instrument was launched, after this testing, at the Adelaide workshop (see below). The instrument is reproduced in Appendix 1. **At present, we are aware of more than 15,000 surveys utilising ASLE(II), which remain to be fully analysed.** A paper discussing the development of ASLE is being prepared for publication.

ASELL Laboratory Program Evaluation (ALPE):

After the first ASELL Directors' Meeting it became clear that there was a need to evaluate a whole laboratory program. The rationale, which was enunciated clearly by the ACDS, was to explore whether the "renovation" of a number of individual experiments would result in an improved student assessment of a whole laboratory program.

The ALPE instrument was developed by the directors to include a series of items that are explicitly linked to the ASLE items to probe whether the promise in ASLE, became reality in ALPE, for example: ASLE: "*It was clear to me how this laboratory exercise would be assessed*", and ALPE: "*It was clear to me how the laboratory program was assessed*". ALPE also include a number of items that are unique to a laboratory program. Specifically, items were included to align with generic attributes of a science graduate, as espoused on the websites of many Australian universities. For example, Item 13 states: "*This laboratory program has developed my ethical awareness*". ALPE also probes transfer of knowledge and skills: "*The knowledge and skills I have learnt elsewhere have been useful in this laboratory program*".

Curtin University was chosen to pilot the ALPE instrument. Baseline ALPE surveys were conducted in Semester 2, 2009 and Semester 1, 2010. ASLE surveys simultaneously conducted to provide information as to where each experiment could be improved. The revised laboratory programs and individual experiments were re-surveyed in Semester 2, 2010 to ascertain if measurable improvements to the student responses to ASLE and ALPE items were identifiable. Table 1 below, using the same ASLE parameterisation of +2 for strongly agree to –2 for strongly disagree, shows that there was a statistically significant improvement for most items measured by ALPE as a result of revisions made to the laboratory programs. This was most significant on the key items of laboratory skills, understanding of chemistry and teamwork, which were targeted for improvement as part of this revision.

Table 1: The average of the parameterised responses to the ALPE instrument across two years before (2009) and after (2010) ASELL-informed revisions made to the program for a single unit of study.

Year	2009	2010
n	116	79
Q1 Data Interpretation	0.86	1.11
Q2 Lab Skills	1.17	1.25
Q3 Research Skills	0.61	0.79
Q4 Interest	0.64	0.91
Q5 Clear Assessment	0.80	0.95
Q6 Understanding of Subject	0.96	1.18
Q7 Demonstrators	1.31	1.41
Q8 Relevance to Degree	1.05	1.05
Q9 Teamwork	1.12	1.23
Q10 Communication Skills	0.70	0.96
Q11 Responsibility for Own Learning	0.87	0.97
Q12 Knowledge/Skills Transfer	0.80	1.00
Q13 Ethics	0.42	0.55
Q14 Overall	0.94	0.95

Aside from the Curtin pilot project, which was overseen by the ASELL Team, the ALPE instrument has been used by another 6 universities to survey 9 lab programs, involving about 2000 student responses (Appendix 4). Although the ASELL Team has access to the data, it remains the property of the host institution and so we will not report further on these data.

3) Professional development for about 90 academic staff through the three Experiential Workshops. Successful attainment of this outcome will be measured by the number of participants at the workshops and by evaluation of workshop survey data.

Our milestone was to provide professional development for 90 academic staff, via three experiential workshops during the course of this project. In reality, seven workshops were run under the auspices of the ASELL project – three concurrently in April 2010 (one each in chemistry, physics and biology), one in October (chemistry and physics) and three concurrently in July 2011 (chemistry, physics and biology). The workshops were geographically diverse, being held in Sydney, Adelaide and Perth. In addition, two further “self-sown” biology workshops were run in Brisbane and Melbourne in June, 2011. These independent workshops were hosted and run by delegates from the Adelaide workshop with only oversight of the ASELL Team (more about this in Community of Practice).

ASELL Experiential Workshop – The University of Adelaide

The first ASELL Workshop was held at The University of Adelaide in April 2010. At this workshop 39 experiments were submitted for evaluation in parallel sessions across the three disciplines, biology, chemistry (including two 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 great 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 registration fee and break-down of expenses are shown in Table 3. 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 the past.

Table 2: (a) Summary of the delegates who attended the 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**

<table>
<tr><th>(b)</th><th>Biology</th><th>Chemistry</th><th>Physics</th></tr>
<tr><td>Total</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td rowspan="4">Types of labs</td><td>Dissection</td><td>Titration</td><td>Pendulum</td></tr>
<tr><td>Botany</td><td>Synthesis</td><td>Radioactivity</td></tr>
<tr><td>Enzymes</td><td>Analytical chemistry</td><td>Optics</td></tr>
<tr><td>Genetics</td><td>Biochemistry</td><td>Oscilloscope</td></tr>
</table>

Table 3: Income and expenses for the ASELL Workshop

Income	Expenses
Registration: $715 per team (academic + student), includes all meals, drink and banquet dinner	Food and Drink during workshop
	Banquet dinner
	Printing of manuals
	Stationery
	Consumables, e.g. chemicals
	Hired help

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 for the experiment they wanted to evaluate to the project manager. After consideration of the types of experiments submitted, academics were notified whether their experiment had been accepted to be evaluated 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 onto 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.

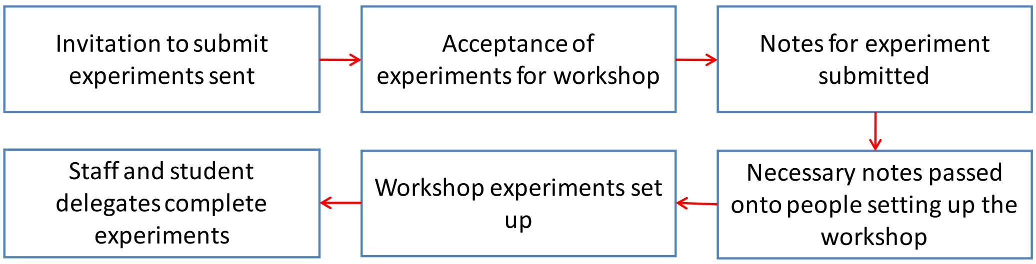


Figure 2: The process undertaken to set up the ASELL Science Workshop held at the University of Adelaide (reproduced from Pyke et al, 2010).

The workshop itself had a very packed schedule. A flowchart of a typical day's events is illustrated schematically by the cycle of photographs in Figure 3. Each day involved early morning discussion sessions focusing 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 completed the same activities as the other delegates.

In the laboratory sessions, academic staff delegates took on the role of a student in testing the experiments, with the exception that the academic who 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 forced to move beyond their comfort zone by undertaking experiments outside of 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 debriefing 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".*

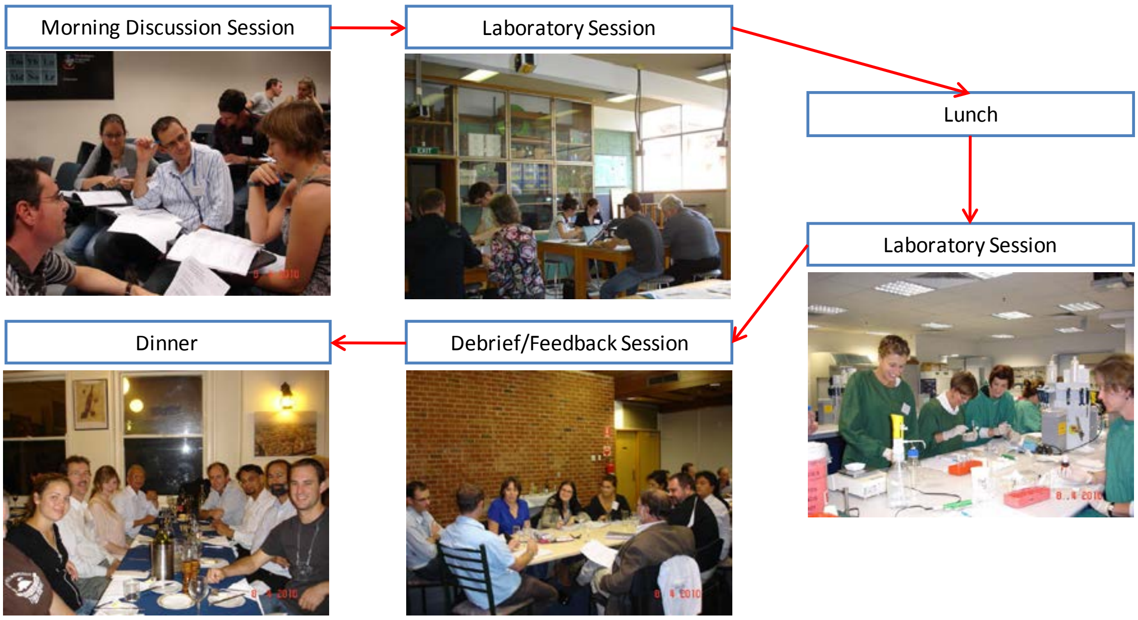


Figure 3: Flowchart of a typical day's events at the ASELL Science Workshop (reproduced from Pyke *et al*, 2010).

ASELL workshop – Curtin University

Another non-experiential ASELL workshop was held in October 2010 at Curtin University. This workshop was treated as a showcase of ASELL activities being conducted at Curtin University where academics from different Western Australian universities were invited to attend. At this workshop, presentations were given by academics, who have conducted their own action-research projects using ASELL principles and feedback they obtained from the ASELL workshop they had previously attended. Not only was this an opportunity for these academics to present their research, it was also an opportunity for people who were not involved with ASELL from Western Australia to hear about the type of activities they could be conducting at their institutions if they were interested. Another reason for holding the workshop in Perth was because the ASELL Team had previously not been able to visit the west coast of Australia to promote the project. Additionally, the workshop was held in conjunction with the ASELL reference group meeting, thereby allowing reference group members to also become aware of the project activities that have taken place and disseminate the project findings.

In total, 47 people attended the Curtin workshop, including members of the reference group and the ASELL Team (Appendix 3). Twenty-nine staff members were new to ASELL. The different institutions represented at the workshop are listed below:

- Curtin University
- Deakin University
- Edith Cowan University
- Flinders University
- Murdoch University
- University of Adelaide
- University of Sydney
- University of Western Australia

In general, the workshop was a success with much discussion about ASELL being initiated with people unfamiliar with the project. It is hoped the workshop has encouraged more people to see the benefit of the project and adopt ASELL principles in their teaching practice.

ASELL Workshop, University of Sydney

A full experimental workshop in all three disciplines was held at The University of Sydney on 14-15 June 2011. The workshop was attended by 22 academic staff and 15 students, most of whom had not attended an ASELL (or ACELL) workshop previously. The workshop was targeted at the broad Sydney-region universities, and delegates came from University of Sydney, UWS, University of Canberra, UTS and University of Wollongong.

The workshop was held following the format of the Adelaide workshop, but with more interaction between the disciplines at lunch, morning and afternoon teas, and the breakout sessions. Nineteen new experiments were trialled and assessed at the workshop.

Summary of ASELL-hosted workshops
A total of 93 academics in biology, chemistry and physics attended at least one of the three ASELL workshops in Adelaide, Perth and Sydney. Fifty eight new experiments were trialled at the workshops, many of which are now on the ASELL database. The workshops acted as a seed for new communities of practice (see below), and were a focus of communication and dissemination between the ASELL Directors, many Deans, and participating academics.

4) New communities of practice in discipline laboratory education. This will be measured by involvement of ASELL participants in local and international conferences, *e.g.*, UniServe Science, Australian Institute of Physics, Royal Australian Chemical Institute, Australian Society for Biochemistry & Molecular Biology.

Since the ASELL workshop was held in April 2010, a number of new communities of practice have established both nationally and internationally, especially in the disciplines of biology and physics, which are in the beginning stages of the project. Although there are currently a limited number of biology or physics experiments on the ASELL website, they are progressively being added. Academics are continuing to conduct their small action research projects, which could later result in a publication on the website and in journals.

ASELL Biology – University of Queensland

A group of biologists at the University of Queensland ran their own local workshop on 9-10 June 2011. The workshop was targeted at the Brisbane universities, and academics and students from The University of Queensland and Griffith University attended. This was advertised on asell.org, and ASELL directors were invited to give “plenary” talks, but the workshop was otherwise fully run and financed locally.

ASELL Biology – Victoria

A group of biology academics from La Trobe University, Monash University and The University of Melbourne ran their own local workshop on 22-23 June 2011 at La Trobe University. In addition to the host institutions, delegates from Deakin University and Swinburne University of Technology attended the workshop. Again, ASELL assisted with some aspects of the planning, and were invited to the workshop, but it was otherwise completely independent.

ASELL Chemistry – Ireland

An ASELL Chemistry workshop was run in July 2010. This workshop was coordinated independently by a group of academics in Dublin after attending a 2-hour ACELL workshop at the Variety (Chemistry Education) Conference in Dublin in 2008.

ASELL – Philippines

Expansion of ASELL principles to the Philippines have took place in 2010 after a group of dedicated chemistry academics obtained funding from the Philippines Commission on Higher Education (CHED) to use ASELL principles as part of teaching practice in the Philippines. The ASELL survey instruments were distributed to 46 institutions across the Philippines at the end of 2010. Results of the surveys were planned to be presented at the 26th Philippines Chemistry Congress in April 2011.

ASELL – United States of America

Funding has been obtained from the National Science Foundation (NSF) to start ASELL Chemistry in the United States of America. Professor Scott Kable was in America in 2010 on study leave. While overseas, Professor Kable collected data using the ASELL survey instruments on an American cohort, as well as promote the project through various presentations around the country. Therefore, relationships with the USA are strong and are likely to not only continue, but also develop as the project grows.

5) Use of the ACDS Network of Associate Deans (L&T) to facilitate further ASELL-style evaluation of laboratory exercises by ASELL-trained staff in their home institution, leading to collegial, internal quality assurance processes being established. The success of this outcome will be gauged by reports from Deans and Associate Deans on the promulgation of ASELL-style laboratory review within their Faculties.

The Australian Council of Deans of Science has been a great supporter of ASELL. Two representative Deans (Professor Lawrance, Flinders University, and Professor Ward, Curtin University) have attended several ASELL meetings, and have advised the ASELL Team in several important regards. The development of a whole laboratory program survey (the ASELL Laboratory Program Evaluation, or ALPE, survey) was at the behest of the Deans, and this has added an extra dimension to analysing the student laboratory experience.

Associate Deans, who are key players for embedding ASELL into faculty practice, were active participants at the Adelaide and Curtin ASELL workshops. They completed the same activities that academics and students did, as well as interacted with other participants, not as an Associate Dean, but as another participant at the workshop. By having firsthand experience of an ASELL workshop and being aware of ASELL principles, it assists them in facilitating further ASELL-style evaluations of laboratory exercises at their home institution.

There have been several examples of ASELL activity inspired at the Dean or Associate Dean level.

- three Associate Deans initiated and/or supported the distribution of ASELL evaluations at their institution for their discipline
- one Associate Dean has volunteered their institution to host an ASELL workshop in the future
- ASELL has become part of the portfolio projects of the Institute for Innovation in Science & Mathematics Education (IISME) at the University of Sydney
- Curtin University has made a fixed term (2 year, Level B) appointment for a person to conduct ASELL surveys on the whole First-Year Chemistry and Physics laboratories.

6) Research outcomes on laboratory learning by students in chemistry, physics and biology will be measured by the conference presentations and journal articles on laboratory learning and professional development by the ASELL Directors.

The ASELL Directors have conducted several avenues of research into student learning in the laboratory, and staff perceptions of such learning, over the course of the project. Specifically, we investigated:

- whether there was any discipline-specific differences in professional development of biology, chemistry and physics staff at an ASELL workshop
- the development and analysis of education research instruments (discussed under 2) above
- academic staff perceptions of laboratory learning, in comparison with student perceptions
- benchmarking Australian staff and student responses with American staff and students.

A short summary of the research outcomes (some incomplete at the time of writing) is provided below.

<u>Comparison with other ASELL workshops</u>

Chemistry workshops in the ACELL project were known to be a successful way to offer PD to chemistry staff, and to engage them in the process of educational research. It was unknown, however, how the chemistry experience would translate into the disciplines of biology and physics. Therefore we conducted research on the delegate experience in the large multidisciplinary Adelaide workshop using the same instrument as previously to compare the responses. If there were differences, it would have implications for the direction of the project. Comparisons were made between delegates' responses between the Sydney 2006 (ACELL), Sydney 2009 (ACELL) and April 2010 (ASELL) workshops. The Sydney 2006 and Sydney 2009 workshops were chosen because they are the most recent workshops of similar size and duration that have been run.

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 4). This might be surprising because 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. 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.

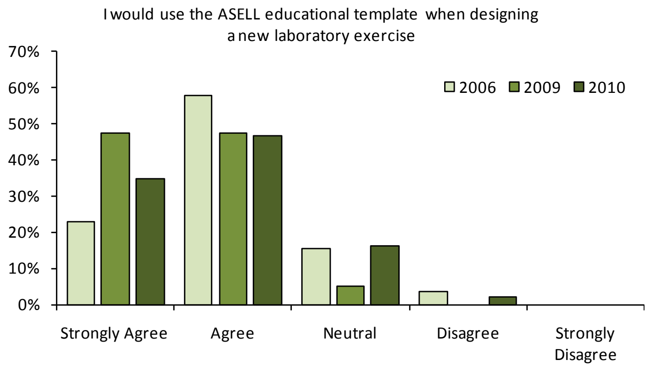


Figure 4: Comparison of academics responses to a question from the workshop evaluation

Furthermore, there were no 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.

In contrast, the student responses across the three workshops using both one-way ANOVA and χ^2 analyses, are statistically different. For example, different distributions of responses arose for the statement “Laboratory exercises are intended to teach more than I had previously realised” [$F_{2,71} = 14.1$, $p = 6.90 \times 10^{-6}$, $\chi^2 = 21.7$, $df = 4$, $p = 2.29 \times 10^{-4}$] (see Figure 5a). A suggested reason for this difference is the demographic variations of the students who attended the workshop over the years (see Figure 5b). 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. 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. Further research about the student background and experience is required to adequately conclude it is the reason for the difference.

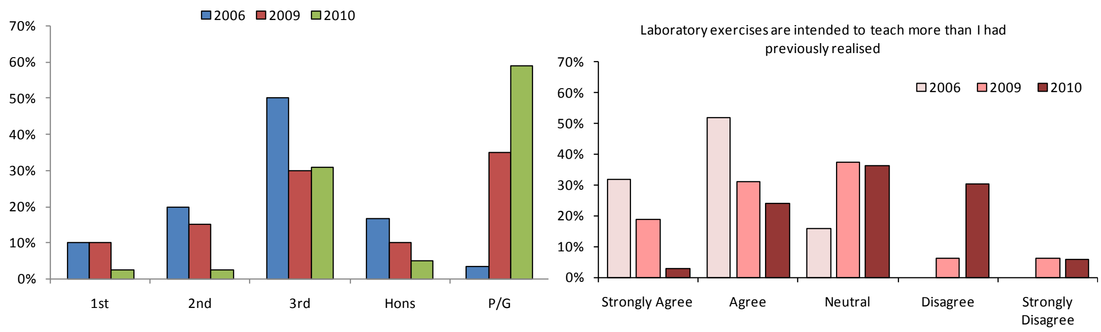


Figure 5: Comparison of (a) student responses to a question from the workshop evaluation and (b) distribution of student population at past workshops

<u>Understanding of academics' perspectives of laboratory work</u>

One of the new research directions, started during the ALTC funding period, was a project to explore the attitudes and perceptions of academic staff towards the teaching laboratory. In particular, via a new instrument, we asked staff about the features or aspects of an undergraduate experiment that they thought would enhance the student experience of that laboratory. The staff were asked specific to predict what **the students** would say when surveyed. The same list of 12 items that appear on the ASLE student survey, with exactly the same form of words, was given to the staff. They were asked to select up to 4 items that they thought would correlate strongly with a positive laboratory experience, and up to 4 items that might not correlate with a positive laboratory experience for students. A copy of the instrument is provided in Appendix 1.

During 2009-10, we surveyed 238 staff across the three enabling sciences (Chemistry/Physics/Biology), in three countries (Australia, USA, England), including 31 Deans, or similar senior staff with administrative responsibilities at a level greater than a School or Department. Table 4 below summarises the distribution.

Table 4: Breakdown of staff respondents by country and discipline.

	Chemistry	Physics	Biology	Deans	Total
Australia	32	31	27	27	117
USA	68	30	5	4	107
England	14	0	0	0	14
Total	114	61	32	31	238

The perceptions of staff across the 3 disciplines was remarkably consistent, as shown in Fig 6 below. The analysis below shows mean score, with standard error for the different 12 items against the score of the whole data set. Biology, Chemistry and Physics correlate with the all staff with R^2 values between 0.82 and 0.90 and 0.93. These correlations show very clearly that staff across 3 disciplines are extraordinarily like-minded about the important factors for a positive laboratory experience for students.

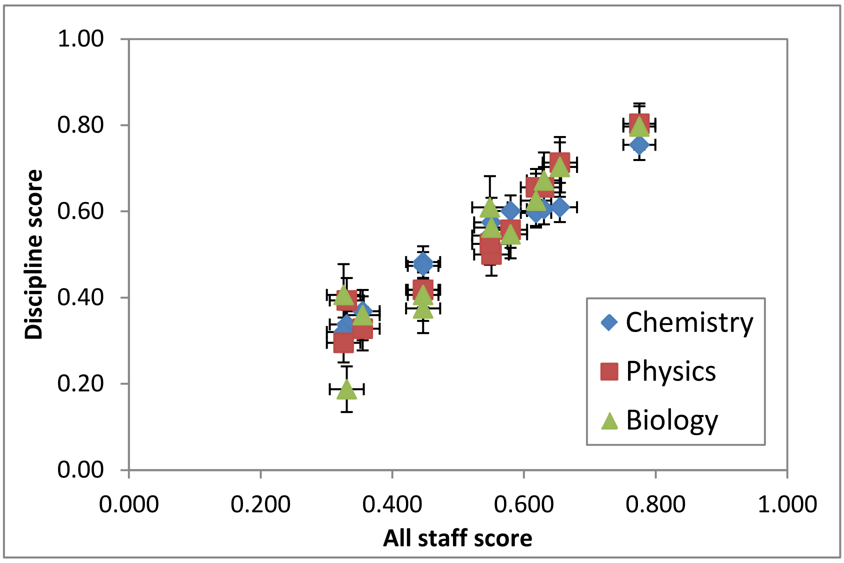


Figure 6: Correlation between academic staff in difference disciplines on the same instrument.

The correlation of the staff responses with the students (N=3000, ASLE instrument) tells a very different story! Ranked highly by staff are factors such as the quality of the demonstrators, and the quality of the practical notes, which students tell us are not two of the 'not important' aspects for a positive laboratory experience. Two of the factors that staff believed NOT to be important factors were "developing data interpretation skills" (ranked 10th) and "opportunity to take responsibility for own learning" (ranked 12th). Students ranked these two items 5th and 1st, respectively.

The analysis of these data is still ongoing. In general terms, the staff responses are more staff-oriented, and less student-focussed.

One of the most important outcomes of this analysis is the recognition that it gives staff that they do not know what the most important factors are for a quality undergraduate laboratory. It becomes much easier to convince staff to learn about laboratory education to empower them with the necessary tools to make a real difference to students in the lab. In addition, these data are providing just the sort of evidence that Deans need to put real resources into staff professional development, and to provide the resources to collect information such as this before expensive laboratory curriculum reform is undertaken.

When coupled with the similarity of responses to the workshop experiences above, we have strong evidence that the laboratory experience across the three disciplines is similar, and that the ASELL approach to laboratory education is valid across science more generally.

<u>Benchmarking with US staff and students</u>

During 2010, 107 academic staff in the USA, and about 250 (chemistry) students were surveyed using the same instruments as the Australian staff and students. The student responses covered 4 First Year undergraduate experiments at one university, while the staff covered chemistry, physics and biology across 7 institutions (large and small, public and private).

The ASLE survey results of the four experiments map directly onto the results of the Australian students. Exactly the same correlations are seen and the same factors that are important to Australian students concerning their laboratory experience are important to the American students.

The staff surveys also showed exactly the same distribution of responses as the Australian staff. There is statistically, no difference between the two cohorts. The combination of these two results, of course, means that academic staff in the USA are equally mis-aligned with their students' perceptions.

The full analysis of this work is being prepared for publication.

7) Developing a sustainable strategy for the ongoing support of ASELL into the future

Although there has been recognition and activity surrounding ASELL that has been promoted by Deans or Associate Deans, this is an area that remains unfulfilled. One early criticism of ACELL (the progenitor project), was that it was reliant on a few strong advocates, and while this remained the case ACELL remained under threat as an ongoing, sustainable activity. The intent within ASELL (the ALTC project) was to move the responsibility of supporting ASELL to the next higher level, where Deans would promote ASELL activities. However, the problem of advocacy remains – just one level higher up the chain. ASELL activities are now promoted in Faculties or Departments where the Dean / Associate Dean is an advocate, rather than where an individual academic is the advocate. The relatively high turnover of Deans and Associate Deans ensures that the current level of advocacy can only drop.

Dissemination

In the broader 'Science' context, ASELL used the same 'engaged and focused' (ALTC Dissemination framework) approach to dissemination, which has proved so successful in the context of Chemistry and ACELL. The strategy has proven its effectiveness in that it has already engaged more than a quarter of the academics teaching chemistry across every university in Australia with a demonstrated impact on student learning recognised by an ALTC Programs Award.

The most direct form of dissemination of the aims, practices and achievements of this project occurred through the academic staff, who participated in the workshops, evaluated the experiments they have proffered, and engaged in laboratory-related action research projects at their various institutions. The most intense, deep form of dissemination involves changes of attitude and perspective of people, and this is notoriously difficult to achieve and measure. The ACELL experience suggests that academics who pair off with a student to do an unfamiliar laboratory experiment and who engage in a real student experience by working from a student laboratory manual can undergo a radical change in their view of laboratory work: its effectiveness, its challenges, and what constitutes best practice (Buntine et al., 2007). This is consolidated when they engage in (probably for the first time) an action research project about "their" experiment and a detailed educational analysis of the experiment for publication. Many experience a realisation that laboratory experiments are not defined by their descriptive titles.

If a critical mass of people participate in workshops and consequently share their experiences with colleagues, the ASELL approach gets analysed and critiqued, emerging in departmental conversations and documents. The presence of the ASELL framework then presents a springboard for driving systematic change, even if the new approach is very different.

Publications of experiments and educational analyses on the project's website or in discipline-specific education journals can lead to an increased level of awareness of non-traditional laboratory formats and, perhaps, of the complexity of curriculum design as it pertains to laboratory work. A number of publications and presentations were achieved this year as described below.

Publications

Published papers:

- Pyke, S. M., Yeung, A., Sharma, M. D., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Lim, K. F. and Kable, S. H. (2010). The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter. In *Proceedings of the 16th UniServe Science Annual Conference*, Sydney, NSW: UniServe Science, 7-12.

- Bhathal, R., Sharma, M. D., & Mendez, A. (2010). Educational Analysis of a First Year Engineering Physics Experiment on Standing Waves: Based on the ACELL Approach. *European Journal of Physics, 31*, 23-35.

- Yeung, A., Sharma, M. D., Pyke, S. M., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Lim, K. F. and Kable, S. H. The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter. *International Journal of Innovation in Science and Mathematics Education*, in press.

- Crisp, M.G., Kable, S.H., Read, J.R. & Buntine, M.A. (2011): *Educational analysis of the First Year undergraduate chemistry experiment 'Investigating Sugar using a Home Made Polarimeter' and a disconnect between staff and student Perceptions of learning*, Chemistry Education Research & Practice, (in press).

Papers in progress:

- Kable et al, paper on the correlations between staff and student perceptions of the factors that influence the overall laboratory learning experience

- Buntine et al, paper on the ASELL instruments and how they can be used to inform the design of laboratory activities

- Sharma et al, paper on the ASELL physics experiments that are currently being redesigned

- Other papers that participants of the ASELL project will write themselves on their submitted experiments

Conference abstracts:

- Yeung, A., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Lim, K. F., Kable, S. H., Pyke, S. M. and Sharma, M. D. (2010). *The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter*, *Proceedings of the Royal Australian Chemical Institute's National Convention,* Melbourne, Australia.

- Southam, D., Mocerino, M., Buntine, M., Zadnik, M., Siddiqui, S., and Ward, J. (2010). *Not all experiments are created equal: ASELL evaluation of a first year laboratory program*, *Proceedings of the Royal Australian Chemical Institute's National Convention*, Melbourne, Australia.

- Kable, S. H., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Lim, K. F., Pyke, S. M. Sharma, M. D. and Yeung, A. (2010). Improving student engagement in the laboratory: An initiative across all Australian universities. Abstracts of Papers, *240th ACS National Meeting*, Boston, MA, United States, August 22-26, 2010 (2010), PRES-14. Publisher: (American Chemical Society, Washington, D. C) CODEN:69NAQG.

- Siddiqui, S., Southam, D., Mocerino, M., Buntine, M., Ward, J., and Zadnik, M. (2010). Applying the ASELL Framework for Improvement of a First Year Physics Laboratory Program. *Proceedings of the 16th UniServe Science Annual Conference*, Sydney, NSW: UniServe Science, 136.

- Buntine, M. A., Southam, D. C., Mocerino, M.,Kable, S. H., Yeung, A., Barrie, S. C., Sharma, M., Lim, K. F., Burke da Silva, K. (2011, 2 August), Active student learning and the ASELL (Advancing Science by Enhancing Learning in the Laboratory) project in Australia, *43rd IUPAC World Chemistry Congress,* San Juan, Puerto Rico (invited keynote).

Conference presentations

A number of conference presentations have also been given by the ASELL Team or participants of the project:

- Yeung, A., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Lim, K. F., Kable, S. H., Pyke, S. M. and Sharma, M. D. (2010, 5 July). *The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter*, The Royal Australian Chemical Institute's National Convention, Melbourne, Australia.

- Southam, D. (2010, 6 July*). Not all experiments are created equal: ASELL evaluation of a first year laboratory program*, The Royal Australian Chemical Institute's National Convention, Melbourne, Australia.

- Kable, S. H., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Lim, K. F., Pyke, S. M. Sharma, M. D. and Yeung, A. (2010, 23 August). *Excellence in the Undergraduate Curriculum - A Global Perspective*, American Chemical Society (ACS) meeting, Boston, Massachusetts, USA (Plenary).

- Pyke, S. M., Yeung, A., Sharma, M. D., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Kable, S. H. and Lim, K. F. (2010, 28 October). *The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter*. 16th UniServe Science Annual Conference, Sydney, NSW (Plenary).

- Siddiqui, S., Southam, D., Mocerino, M., Buntine, M., Ward, J., and Zadnik, M. (2010, 28 October). *Applying the ASELL Framework for Improvement of a First Year Physics Laboratory Program*. 16th UniServe Science Annual Conference, Sydney, NSW.

Invited talks

The ASELL Team has been invited to give presentations at various events and universities:

- Lim, K. F., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Kable, S. H., Pyke, S. M. Sharma, M. D. and Yeung, A. (2010, 23 March). *Improvements in teaching and learning can be linked to C1 research papers for "average" science academics*, La Trobe University, Bundoora.

- Pyke, S. M., Sharma, M. D., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Kable, S. H., Lim, K. F., and Yeung, A. (2010, 15 July). ACDS Teaching and Learning Conference, Sydney.

- Pyke, S. M., Sharma, M. D., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Kable, S. H., Lim, K. F., and Yeung, A. (October 2010, October). ACDS AGM, Sydney.

- Kable, S. H., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Lim, K. F., Pyke, S. M. Sharma, M. D. and Yeung, A., *The Advancing Science by Enhancing Learning in the Laboratory (ASELL)*, invited seminars at Univ. New Mexico, Drake Univ., Univ. Wisconsin, Emory Univ., Georgia Tech., Univ. California, Davis, Florida Atlantic Univ., and Marquette Univ. (June-Nov, 2010)

Workshop presentations

- Pyke, S. M., Yeung, A., Sharma, M. D., Barrie, S. C., Buntine, M. A., Burke Da Silva, K., Kable, S. H. and Lim, K. F. (2010, 28 October). *The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter*. ASELL Workshop at Curtin University.

- Siddiqui, S., Southam, D., Mocerino, M., Buntine, M., Ward, J., and Zadnik, M. (2010, 11 October). *Applying the ASELL Framework for Improvement of a First Year Physics Laboratory Program*. ASELL Workshop at Curtin University.

- Southam, D., Mocerino, M., Buntine, Zadnik, M., Siddiqui, S., and Ward, J. (2010, 11 October*). Not all experiments are created equal: ASELL evaluation of a first year laboratory program*, ASELL Workshop at Curtin University.

- Zadnik, M., Southam, D., Mocerino, M., Buntine, M., Ward, J., and Siddiqui, S. (2010, 11 October). *The "Simple Pendulum" Experiment: Not So Simple.* ASELL Workshop at Curtin University.

- Burke Da Silva, K., Yeung, A., Barrie, S. C., Buntine, M. A., Kable, S. H., Lim, K. F., Pyke, and S. M. Sharma, M. D. (2010, 17 August). A. *Making Laboratory Exercises Good Learning Experiences: The ASELL Project*, ASELL Philippines Introductory Seminar, Makati City, Philippines.

Linkages

Connection to ALTC Mission, Objectives and Aims

The ASELL Project focuses on Priority Area 1 of the ALTC Competitive Grants program- *'Research and development focussing on issues of emerging and continuing importance'* by targeting enhancements in laboratory learning, which is a central area of science education.

The ASELL Project has very clear overlap with three of the ALTC objectives. Specifically, ASELL will clearly *promote and support strategic change in higher education institutions for the enhancement of teaching and learning (Obj. a)*, by providing validated experiments and PD, in a collegial manner, that will lead to measurably better student laboratory experiences. The objective has been achieved.

A specific goal of this project is to *develop effective mechanisms for the identification, development, dissemination and embedding of good individual and institutional practice in L&T in Australian higher education (Obj. d)*. ASELL provides both cross-institutional fertilisation of good practice at discipline workshops, and cross-discipline communication via the embedding of ASELL practices at the level of Deans and Associate Deans (L&T). This goal has been achieved.

ASELL adopts a *national approach* to supporting PD, and thus academic staff will be empowered to *identify issues that impact L&T on their own ground (geographical or discipline)* (*Obj. f*). The original ACELL aim in 1999 is equally valid to ASELL in 2009, which is *to treat all science faculties in Australia as one big science faculty and to share the best laboratories and the best L&T practice to the benefit of everyone.*

Connection to the other ALTC projects

The ASELL Project is closely related to the ALTC projects *Tertiary Science Education in the 21st Century* and *Forging New Direction in Physics Education in Australian Universities*. There is also considerable common ground between the ASELL Project and the *Tertiary Science Education in the 21st Century* Project led by Professor Sue Thomas and Professor John Rice. In particular, the ACDS project examined the role of laboratories in biology, chemistry and physics, while the ASELL project evaluates the laboratory experiences of students.

The *Forging New Direction in Physics Education in Australian Universities* Project led by Associate Professor Les Kirkup and Associate Professor Manjua Sharma played an important role in the expansion of ACELL to ASELL. As a consequence of that project, strong links were formed with the ASELL Team and the ACDS. A workshop was organised at UTS in 2007 to trial the ACELL methodology in the discipline of physics. This workshop was attended by the president of the ACDS and was partially sponsored by the ACDS. That workshop drew together ACELL Directors, and physics academics and students. The whole day workshop was a success and has allowed productive relationships to develop between ASELL and the ACDS. Additionally, as a result of the tangible outcomes of the workshop, collaborations were established; in particular, the leader of the *New Direction in Physics Education in Australian Universities* Project is now the leader of the physics component of the ASELL Project.

The ACDS, in particular the ACDS Project Leaders of the *Tertiary Science Education in the 21st Century* Project, have encouraged and supported the ASELL Project and it's expansion from ACELL to ASELL. The ACDS has not only supported the trial Physics workshop, but also the ASELL Science Workshop held in April as well as other ASELL events. The ASELL Team is continually working with the ACDS to establish national communities of practice in ASELL methodology supported by managed science faculty engagement.

Evaluation

Evaluation of the workshop

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 on each experiment they tested – one relating to the actual experiment and one about 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 submitted experiment were returned to the submitter before leaving the workshop, which was not previously done in the past. This allowed them to make immediate changes when they returned home, rather than have 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, and 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 5-point Likert Scale 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.

In addition, the ASELL Workshop Evaluation included four open-ended questions:

- What did you find to be the most valuable aspect of the ASELL workshop? Why?
- What area of the workshop do you think most needs to be improved? What improvements would you suggest?
- What was the thing at the workshop which you found most surprising?
- Please provide any additional comments on the workshop here

Delegate responses 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, Buntine, Crisp, Barrie, George, Kable, Bucat, & Jamie, 2006). Table 5 shows the coding categories, as well as the number of positive and negative delegate responses. Almost all comments were allocated to one category. Once categorised, all comments were classified as either 'positive' or 'negative'.

The following sections will be discussed according to each of the coding categories shown in Table 5.

Delegate interaction (DI)

Academic and student delegates were each asked 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 7a).

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	124	63	187	76	53	129	316

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 7b) because working as a student on an experiment is something that 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 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.

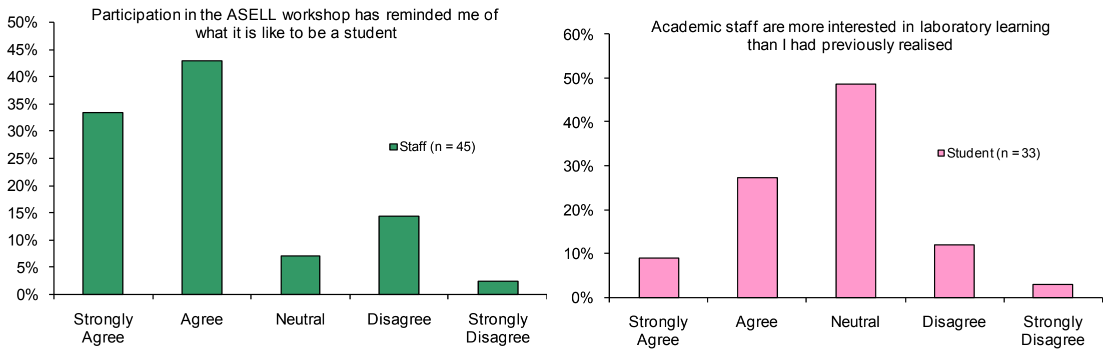


Figure 7: Delegate responses to Likert scale items on delegate interactions

Delegate responses to the open-ended questions in 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 7. 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 would interact with each other due to the packed 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)
- "It might be useful to have cross-disciplinary interaction. Sharing a room with someone from physics led to some useful discussions (student)"
- "I was hoping to have had the chance to participate in a different discipline's experiment (student)"
- they wanted "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)

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 value 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 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"*

satisfying another aim of the project.

Educational Aspects

According to the workshop evaluation, both academics and students agreed that participation in the workshop has led to an improvement in the understanding of educational issues (Figure 8) on the -2 to +2 scale. The mean response of students of +1.52 (σ = 0.57) was slightly more positive than the mean academic response of +1.33 (σ = 0.76), however the difference was not statistically significant [t_{77} = 1.21, p = 0.231]. This is not surprising as the workshop allowed delegates to think about educational issues uninterrupted and facilitated by the immersion nature of the workshop design.

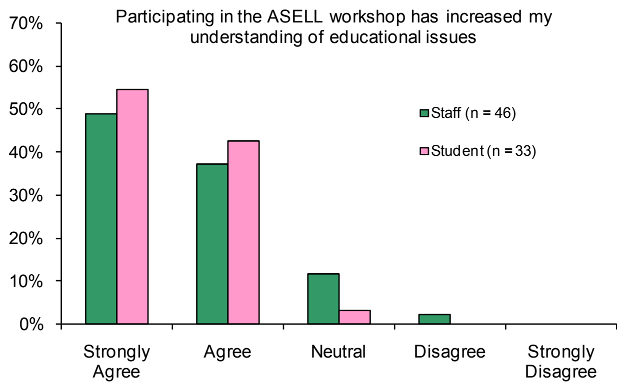


Figure 8: Delegate responses to Likert scale items on Educational Aspects

Delegate responses to the open-ended questions in the EA category covered themes such as delegate educational awareness, and quality/effectiveness of laboratory exercises. Similar to the DI category, there were significantly more positive responses than negative responses for both academics and students [χ^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 9 presents the Likert scale items, to which only academics responded. 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.

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 due to some academics who attended the 2010 workshop have also attended a previous ASELL workshop or have been exposed to ASELL principles. Fourteen academics (31 %) reported that they have 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 don't have an understanding of educational aspects of laboratory learning. Rather, they might already have a good understanding from attending other ASELL events and they didn't 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".

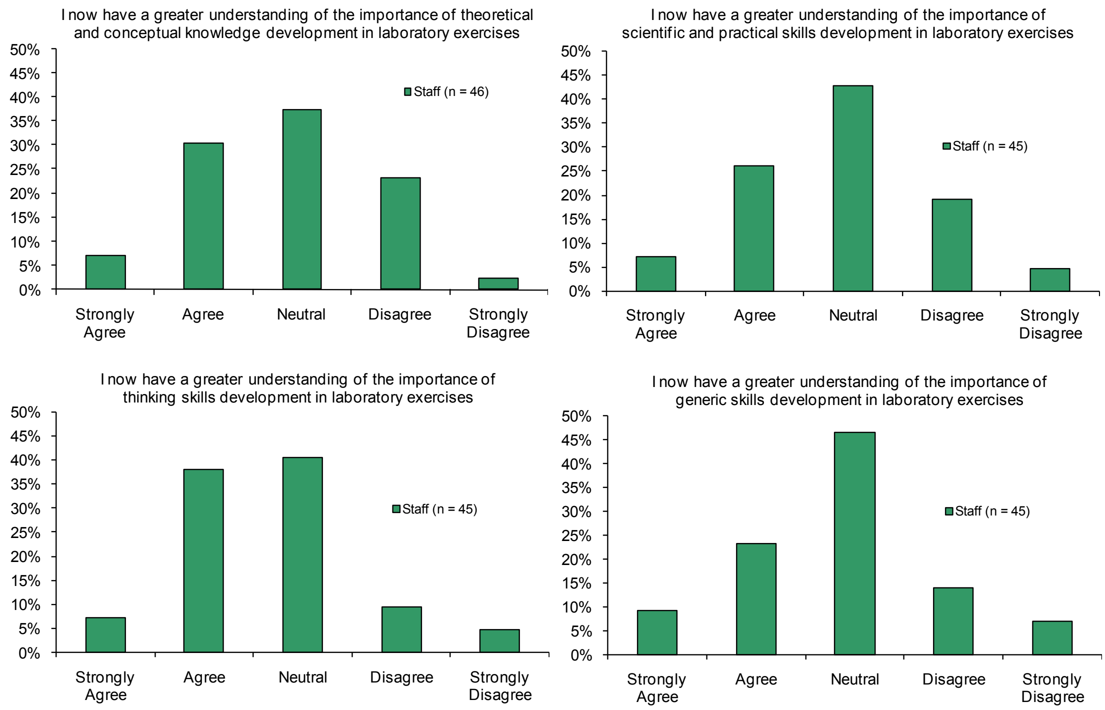
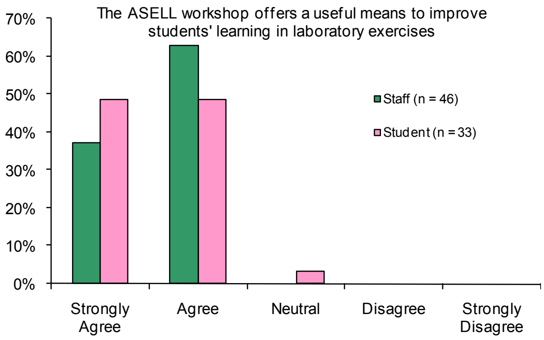
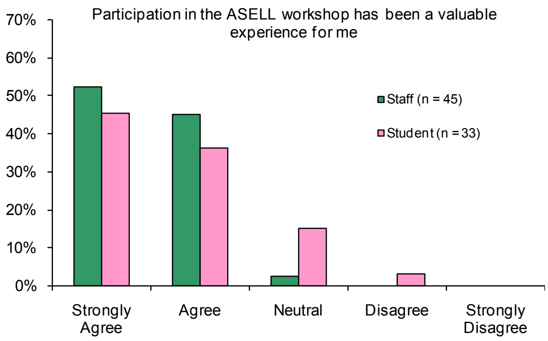


Figure 9: Academic responses to Likert scale items on Educational Aspects included in the ASELL Workshop Evaluation Survey

Workshop Design (WD)

Academics and students report a positive response to the two Likert scale items concerning the structure and design of the workshop (see Figure 10). For the question "The ASELL workshop offers a useful means to improve students' learning in laboratory exercises”, the mean academic response was 1.37 (σ = 0.49) and the mean student response was 1.45 (σ = 0.56) on the +2 to -2 scale. 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 (σ = 0.55) and the mean student response was 1.24 (σ = 0.83). Again, no significant difference was found for the two groups [$\chi^2 = 207$, $df = 1$, p = 0.649], indicating that the workshop design was





beneficial for both academics and students.

Figure 10: 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 demonstrate that delegates showed a high level of engagement with the process. For example, many delegates had comments like

- *“More time 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

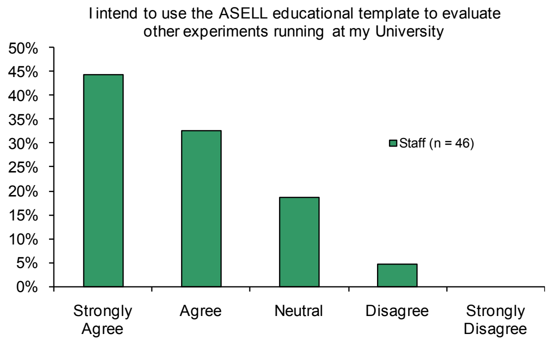
"the whole process is excellent. It seems to really help academics to relive the students experience momentarily and gain valuable insight for improvements to their teaching and learning practices".

Student comments on the ASELL process and their experience of it were 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 % intend to use it to evaluate experiments and 81 % intend to use it when designing new laboratory exercises (see Figure 11). 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).*



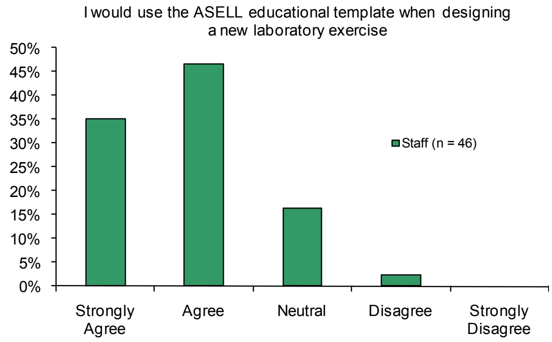


Figure 11: Academic responses to Likert Scale items concerning the ASELL Educational Template

Formative evaluation

Various methods of formative evaluation have been used.

Throughout the project there were emails between the project leaders and the project officer on the execution of the project. Meetings were also arranged to discuss the achievements of the project, what needed to be done and how to move the project forward. These meeting were either purposely organised or opportunistic by linking it with a conference or workshop. Each meeting was very productive and led to ideas of events and actions to take place to move the project forward.

During the ASELL workshop, some participants made comments (in passing) concerning what they thought about the workshop and some of the logistics. A few of these comments were taken into consideration and were implemented where possible during the workshop. For example, participants preferred to receive all surveys relating to the experiments they completed immediately after rather than during the de-brief session in the evening so that they have more time to complete the survey. This suggestion was implemented on the second day of the workshop.

After the workshop, an email was sent to the University of Adelaide technical staff and post-graduate students who assisted in setting up the experiments that were run at the experiential workshops. A small number of questions were asked such as:

- What did they think about the experience? Would you do it again?
- How easy was it to set up someone else's experiment?
- Were there any major issues? How were they resolved?

- Do you have any suggestions on how things should be done if another workshop is run in the future?

Although only a limited response was received from the postgraduate students who set up the ASELL Science Workshop, their comments were helpful and can be used the next time a workshop is organised. For example, one postgraduate student found it difficult to set up an experiment from another institution and thought that it was important for communication to exist between the people setting up the experiment and the technical staff from the home institution of the experiment.

Feedback on the progress of the project was also received at various conferences and workshops. Although attendance at these events was mainly to disseminate the research conducted of the ASELL Project, feedback was freely given by delegates of these events.

Summative evaluation

In essence, the summative evaluation has been described in the *project outcomes and deliverables* section of this report. We believe that we have achieved our aims and have delivered on our deliverables. In some cases, opportunities arose that were unanticipated and has benefited the project. For example, funding to establish ASELL in the Philippines was not expected and has been welcomed.

Independent evaluation

Professor Ian Johnston (The University of Sydney, retired), was appointed as an external evaluator for the project. Professor Johnston has prior experience as an ALTC evaluator, and has had no involvement with the project at any stage of its lifecycle.

Professer Johnston attended the Sydney workshop in June 2011, interviewed staff and students at the workshop, interviewed Directors and members of the advisory committee, read all ASELL documents, and was given full access to the database.

His report is available as a separate report to the ALTC.

Factors critical to success

The success of the project arose from a number of critical factors. They were:

The project manager having the skills and commitment to manage the project: The project manager was a key person to keep the project on track and maintain momentum. The skills and commitment of the project manager were vital for all aspects of the project to have taken place. The role of the project manager is also important as the project Team have their own commitments as academics and needed to project manager to step in and implement ideas and visions of the project.

Deans being strong advocates of the project: The Deans and Associate Deans of the participating institutions and members of the ACDS were vital for the success of the project. Firstly, they supported the running of the ASELL workshop in Adelaide and distributed letters to schools within their institutions encouraging academics and students to attend the workshop. Secondly, they Deans provided financial support ($1500) for a team (one academic and one student) from each discipline (biology, chemistry and physics) to attend the workshop. Thirdly, a number of Deans, Associate Deans or their representatives attended the special ASELL Deans workshop held in Adelaide and participated in all activities. Without their support for the project, the workshop would not have been such a success and the follow-up response from the workshop would not have been possible.

A highly motivated and committed project Team: The project Team are all highly motivated and committed to the project. Communication amongst the Team was vital and well as the dedication the Team members had for the project. Without the input each member made to the different phases of the project, it would not have developed to where it is today.

Academics committed to improving their experiments and laboratory programs: Academics who are committed to improving the experiments at their institution are important players in the project. One of the key aims of the project is to provide PD to staff. If academics were not keen in developing PD through ASELL, we wouldn't have as much data as we have to help us further inform teaching. This is because the academics would not have actively tried to survey their students with the ASELL survey instruments.

Institutional buy-in from academic staff, as well as technical staff of the host institutions for the workshops: The institutional buy-in from the host institutions was extremely critical and needs to be strongly considered when any workshop is run, both experiential or not. Since the project manager was based at the host institution, without the support from academic staff, administration staff, technical staff or PhD students hired to set up experiments for the workshop, the workshop would not have taken place. Buy-in from technical staff was especially important when running the ASELL workshop in Adelaide as submitted experiments were not from the host institution and there was added stress of setting up a new experiment.

Many challenges arose while setting up for the ASELL Workshop held in Adelaide. Firstly, it was difficult to determine the discipline in which the two biochemistry experiments would be tested. 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 6 shows the number of people who were required to set up the experiments for each discipline.

Table 6: 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 brains from a particular species for a brain dissection experiment

Due to a shortage of technical staff available in the physics department, academics that 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, 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 such material or equipment were 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.

The Workshop held at Curtin University was easier to organise because experiments were not required to be set up. However, more assistance was required to set-up a teleconference to the USA for the reference group meeting.

Factors that impeded progress

A number of factors had the potential to impede the project. Although these factors are negative, they did not impact of the project too much.

Weaknesses in ACELL methodology: Whilst ACELL has widely recognised for its contribution to professional development and laboratory curriculum renewal, the impact of the project remains manifest in a number of enthusiastic individuals who have participated in the project. Over time this impact diminishes as the workshop experience recedes and as new staff take over laboratories. In essence, the professional development and the ensuing community of practice have not yet been embedded into normal academic business. (To be fair, embedding ACELL practice into Faculty practice was not an original ACELL objective. It appears here as an ASELL objective for the first time.) In a series of meetings over the past 18 months, the Australian Council of Deans of Science (ACDS) has become an enthusiastic supporter of the ACELL methodology and seeks to redress this weakness by providing a means to embed ACELL programs into Faculty operations so that it becomes self-perpetuating and self-sustaining. This is still currently taking place and without the support of the Deans, the project would not be have progressed as far as it has.

Over-commitment of members of the project Team: It is not uncommon for academics to be involved in many activities concurrently, related or unrelated to the project. Effective mechanisms were used to ensure that deadlines were met and events were organised in a timely manner with as much input from the project Team as possible. This was mainly achieved through good communication and good organisation with the project manager.

Concluding Remarks

Most of the aims of this project have been fulfilled, some far exceeded:

i) the project has resulted in a web-based database of 100 experiments, all scientifically and educationally tested, that are available for download by any academic who registers with the website

ii) almost 100 academic staff in biology, chemistry and physics have had professional development through attendance at an ASELL workshop in the past 18 months. When combined with workshop delegates at past ACELL workshops, about 200 Australian academics have attended an ACELL/ASELL workshop

iii) new survey instruments have been developed and tested, and earlier instruments updated, following educational and statistical analysis. About 15,000 surveys have been received over the course of the ALTC project. When added to the 3000 under the previous ACELL project, many more surveys in the current semester that have not yet been returned to ASELL, it is likely that over 20,000 ASELL surveys have been implemented. This is both a rich vein of research for better understanding the student laboratory learning experience, and, more importantly, very strong evidence that ASELL tools are being used widely to improve the laboratory experience for students throughout the country

iv) research by the ASELL Team has led to new understanding of the way that staff think about laboratory learning. Staff are remarkably similarly minded across the fields of biology, chemistry and physics, and between the US and Australia. However, their thinking is not in line with student assessment of their laboratory experience

v) participation in ASELL has enabled new communities of practice focussed on laboratory learning to emerge in the fields of biology and physics, and in overseas locations, including the Philippines and USA. ASELL has been invited to run a workshop in India in 2012.

The biggest unresolved issue is how to maintain the level of activity evident through 2009-11, whilst operating under the ALTC grant. ASELL has gained significant traction in the Australian Council of Deans of Science. However, although Deans now recognise ASELL as an important academic activity, there remains a question as to whether support through the ACDS is the appropriate mechanism to actually fuel further ASELL activity. The University of Sydney has incorporated ASELL activity into one of the specific projects of a new institute, called the Institute for Innovation in Science and Mathematics Education (IISME). It seems clear that ASELL activities will continue to be fostered through this mechanism, and it seems that incorporation of ASELL into similar bodies in other universities might be a better way to ensure sustainable activity in ASELL.

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References

Barrie, S. C., Buntine, M. A., Jamie, I. M., & Kable, S. H. (2001a). *APCELL: Developing Better Ways of Teaching in the Laboratory*. Paper presented at the Research and Development into University Science Teaching and Learning Workshop.

Barrie, S. C., Buntine, M. A., Jamie, I. M., & Kable, S. H. (2001b). *APCELL*: The Australian Physical Chemistry Enhanced Laboratory Learning Project. *Australian Journal of Chemical Education, 57*, 6-12.

Barrie, S. C., Buntine, M. A., Jamie, I. M., & Kable, S. H. (2001c). Physical Chemistry in the Lab. *Chemistry in Australia, 68*(2), 37-38.

Bennett, S. W. (2000). University Practical Work: Why Do We Do It? *Education in Chemistry, 37*, 49-50.

Bennett, S. W., & O'Neale, K. (1998). Skills Development and Practical Work in Chemistry. *University Chemistry Education, 2*, 58-62.

Bodner, G. M. (1986). Constructivism: A Theory of Knowledge. *Journal of Chemical Education, 63*, 873-878.

Bodner, G. M., MacIsaac, D., & White, S. R. (1999). Action Research: Overcoming the Sports Mentality Approach to Assessment/Evaluation. *University Chemistry Education, 3*, 31-36.

Boud, D., Dunn, J., & Hegarty-Hazel, E. (1986). *Teaching in Laboratories*. Guilford, Surrey: SRHE & NFER-Nelson.

Buntine, M. A., Read, J., R., Barrie, S. C., Bucat, R. B., Crisp, G. T., George, A. V., Jamie, I. M., & Kable, S. H. (2007). Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL): A Model for Providing Professional and Personal Development and Facilitating Improved Student Laboratory Learning Outcomes. *Chemistry Education Research and Practice, 8*(2), 232-254.

Coe, E. M., McDougall, A. O., & McKeown, N. B. (1999). Is Peer-Assisted Learning of Benefit to Undergraduate Chemists? *University Chemistry Education, 3*, 72-75.

Crisp, M.G., Kable, S.H., Read, J.R. & Buntine, M.A. (2011): *Educational analysis of the First Year undergraduate chemistry experiment 'Investigating Sugar using a Home Made Polarimeter' and a disconnect between staff and student Perceptions of learning*, Chemistry Education Research & Practice, (in press).

Crotty, M. (1998). *The Foundations of Social Research*. Sydney: Allen & Unwin.

Del Carlo, D. I., & Bodner, G. M. (2004). Students' Perceptions of Academic Dishonesty in the Chemistry Classroom. *Journal of Research in Science Teaching, 41*, 47-64.

Denzin, N. K., & Lincoln, Y. S. (1994). *Handbook of Qualitative Research*. Thousand Oaks: Sage Publications.

Deters K.M., (2005), Student opinions regarding inquiry-based labs, *Journal of Chemical Education*, *82*, 1178-1180.

Domin, D. S. (1999). A Review of Laboratory Instructional Styles. *Journal of Chemical Education, 76*, 543-547.

Froyd, J., & Layne, J. (2008, October 2008). *Faculty Development Strategies for Overcoming The "Curse of Knowledge".* Paper presented at the 38th ASEE/IEEE Frontiers in Education Conference.

Green, W. J., Elliott, C., & Cummins, R. H. (2004). "Prompted" Inquiry-Based Learning in the Introductory Chemistry Laboratory. *Journal of Chemical Education, 81*, 239-241.

Hartley, D. (2007). Emergence of Distributed Leadership in Education: Why Now? *British Journal of Education Studies, 55*, 202-214.

Hegarty-Hazel, E. (Ed.). (1990). *The Student Laboratory and the Science Curriculum*. London: Routledge.

Henderson, C., & Dancy, M. H. (2007). Barriers to the Use of Research-Based Instructional Strategies: The Influence of Both Individual and Situational Characteristics. *Physics Review Special Topics - Physics Education Research, 3*, 1-14.

Hofstein, A., & Lunetta, V. N. (1982). The Laboratory in Science Teaching: Neglected Aspects of Research. *Review of Educational Research, 52*, 201-217.

Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundation for the 21st Century. *Science Education, 88*, 28-54.

Hofstein, A., & Mamlok-Naaman, R. (2007). The Laboratory in Science Education: The State of the Art. *Chemistry Education Research and Practice, 8*(2), 105-107.

Hunter, W. J. F. (2007). Action Research as a Framework for Science Education Research. In G. M. Bodner & M. Orgill (Eds.), *Theoretical Frameworks for Chemistry/Science Education* (pp. 152-171). Upper Saddle River, NJ: Pearson Education Publishing.

Irby, D. M. (1996). Models of Faculty Development for Problem-Based Learning. *Advanced Health and Science Education*(1), 69-81.

Jamie, I. M., Read, J. R., Barrie, S. C., Bucat, R. B., Buntine, M. A., Crisp, G. T., George, A. V., & Kable, S. H. (2007). From APCELL to ACELL and Beyond - Expanding a Multi-Institution Project for Laboratory-Based Teaching and Learning. *Australian Journal of Chemical Education, 67*, 7-13.

Johnstone, A. H. (1997). Chemistry Teaching - Science or Alchemy? 1996 Brasted Lecture. *Journal of Chemical Education, 74*, 262-268.

Johnstone, A. H., & Al-Shuaili, A. (2001). Learning in the Laboratory: Some Thoughts from the Literature. *University Chemistry Education, 5*, 42--51.

Krockover, G., Adams, P., Eichinger, D., Nakhleh, M., & Shepardson, D. (2001). Action-Based Research Teams: Collaborating to Improve Science Instruction. *Journal of College Science Teaching, 30*, 313-317.

Lim, K. F. (2009). The Australian Journal of Education in Chemistry. *Chemistry in Australia, 76*(2), 20-22.

Mayer, R. E. (2004). Should There Be a Three-Strikes Rule against Pure Discovery Learning? The Case for Guided Methods of Instruction. *American Psychologist, 59*, 14-19.

Moore, J. W. (2006). Let's Go for an A in Lab. *Journal of Chemical Education, 83*, 519.

Osbourne, J., Simon, S., & Collins, S. (2003). Attitudes Towards Science: A View of the Literature and Its Implications. *International Journal of Science Education, 25*, 1049-1079.

Palinscar, A. S. (1998). Social Constructivists Perspectives on Teaching and Learning. *Annual Review of Psychology, 49*, 345-375.

Paris, S. G., & Turner, J. C. (1994). Situated Motivation. In P. R. Pintrich, D. R. Brown & C. E. Weinsein (Eds.), *Student Motivation, Cognition and Learning* (pp. 213-237). Hillsdale, NJ: Erlbaum.

Psillos, D., & Niedderer, H. (Eds.). (2002). *Teaching and Learning in the Science Laboratory*. Dordrecht, Netherlands: Kluwer Academic Publishers.

Pyke, S. M., Yeung, A., Sharma, M. D., Barrie, S. C., Buntine, M. A., Silva, K. B. D., Kable, S. H., & Lim, K. F. (2010). *The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter.* Paper presented at the Proceedings of the 16th UniServe Science Annual Conference, Sydney, NSW.

Read, J., R. (2006a). Achievement of an ACELL Workshop. *Chemistry in Australia, 73*(9), 17-20.

Read, J., R. (2006b). The Australian Chemistry Enhanced Laboratory Learning Project. *Chemistry in Australia, 73*(1), 3-5.

Read, J., R., Buntine, M. A., Crisp, G. T., Barrie, S. C., George, A. V., Kable, S. H., Bucat, R. B., & Jamie, I. M. (2006). *The ACELL Project: Student Participation, Professional Development, and Improving Laboratory Learning.* Paper presented at the Proceedings of the Assessment in Science Teaching and Learning Symposium, Sydney, NSW.

Read, J.R and Kable, S.H. (2007). *Educational analysis of the first year chemistry experiment 'Thermodynamics Think-In': an ACELL experiment.* Chemistry Education Research and Practice, *8*, 255-273.

Reid, N., & Shah, I. (2007). The Role of Laboratory Work in University Chemistry. *Chemical Educator, 8*, 172-185.

Rice, J. W., Thomas, S. M., & O'Toole, P. (2009). *Tertiary Science Education in the 21st Century*. Sydney: Australian Learning and Teaching Council.

Royal Australian Chemical Institute. (2005). The Future of Chemistry Study: Supply and Demand of Chemists. from http://www.raci.org.au/national/downloads/Future%20of%20Chemistry%20Report.pdf

Sandretto, S., Kane, R., & Heath, C. (2002). Making the Tacit Explicit: A Teaching Intervention Programme for Early Career Academics. *International Journal of Academic Development, 7*, 135-145.

Sharma, M. D., & McShane, K. (2008). A Methodological Framework for Understanding and Describing Discipline-Based Scholarship of Teaching in Higher Education through Design-Based Research. *Higher Education Research and Development, 27*(3), 257-270.

Sharma, M. D., Mills, D., Mendez, A., & Pollard, J. (2005). Learning Outcomes and Curriculum Development in Physics. 41. Retrieved from http://www.physics.usyd.edu.au/super/AUTC/

Shibleym, I. A., & Zimmaro, D. M. (2002). The Influence of Collaborative Learning on Student Attitudes and Performance in a Chemistry Laboratory. *Journal of Chemical Education, 79*, 745-748.

Sidell, M. (1993). Interpreting. In P. Shakespeare, D. Atkinson & S. French (Eds.), *Reflecting on Research Practice: Issues in Health and Social Welfare* (pp. 106-118). Buckingham, UK: Open University Press.

Skinner, E. A., & Belmont, M. J. (1993). Motivation in the Classroom - Reciprocal Effects of Teacher-Behaviour and Student Engagement across the School Year. *Journal of Educational Psychology, 85*, 571-581.

Spillane, J. P., Halverson, R., & Diamond, J. B. (2004). Towards a Theory of Leadership Practice: A Distributed Perspective. *Journal of Curriculum Studies, 36*, 3-34.

The Design-Based Research Collective. (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Education Researcher, 32*(1), 5-8.

Wenger, E. (2007). Communities of Practice. A Brief Introduction. *Communities of practice*. Retrieved from http://www.ewenger.com/theory/

Appendices

Appendix 1: Survey instruments used in the project

- *ASELL Student Learning Experience (ASLE) Survey*
- *ASELL Laboratory Program Evaluation (ALPE) Survey*
- *Staff Survey*
- *Workshop ASLE*
- *Workshop Evaluation*

Appendix 2: ASELL Educational Template Resources

- ASELL Educational Template
- Information about the ASELL Educational Template

Appendix 3: Workshop Materials

- Workshop program – University of Adelaide
- List of participants – University of Adelaide
- List of experiments – University of Adelaide
- Workshop program – Curtin University
- List of participants – Curtin University
- List of presentations – Curtin University

Appendix 4: Summary of data collected

- ASLE
- ALPE

Appendix 1: Survey instruments used in the project

ASELL Student Learning Experience (ASLE) Survey

Name of Experiment **Date**

This experiment has been submitted to ASELL for evaluation. An important part of this evaluation process involves collecting feedback on students' experience of the exercise, which is the purpose of this survey. Your responses are anonymous, and participation is voluntary. Put your responses under ANSWERS on the right hand side of this form. If you feel you cannot answer a particular question, just leave it and go onto the next question. Erase errors thoroughly. Please note that the scale below should be used for ***only*** questions 1 to 12, as 13 and 14 have separate scales. Also, the survey is double-sided.

	A	B	C	D	E
SCALE:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

1. This [experiment] helped me to develop my data interpretation skills . . . .
2. This [experiment] helped me to develop my laboratory skills. . . . .
3. I found this to be an interesting [experiment]. . . . .
4. It was clear to me how this [laboratory exercise] would be assessed. . . . .
5. It was clear to me what I was expected to learn from completing this [experiment]. . . . .
6. Completing this experiment has increased my understanding of [discipline]. . . . .
7. Sufficient background information, of an appropriate standard, is provided in the introduction. . . .
8. The demonstrators offered effective supervision and guidance. . . . .
9. The [experimental procedure] was clearly explained in the lab manual or notes. . . . .
10. I can see the relevance of this [experiment] to my [discipline] studies. . . . .
11. Working in a team to complete this [experiment] was beneficial. . . . .
12. The [experiment] provided me with the opportunity to take responsibility for my own learning

FOR EACH OF THE NEXT TWO QUESTIONS, USE THE SEPARATE SCALES INDICATED

13. I found that the time available to complete this [experiment] was . . . .
    A = 'way too much' **B** = 'too much' **C** = 'about right' **D** = 'not enough' **E** = 'nowhere near enough'
14. Overall, as a learning experience, I would rate this experiment as . . . .
    A = 'excellent' **B** = 'good' **C** = 'average **D** = 'poor' **E** = 'very poor'

Please turn over and complete the additional questions on the back of this form.

15. Did you enjoy doing the experiment? Why or why not?

16. What did you think was the main lesson to be learnt from the experiment?

17. What aspects of the experiment did you find most enjoyable and interesting?

18. What aspects of the experiment need improvement and what changes would you suggest?

19. Please provide any additional comments on this experiment here.

Please place this survey in the box at the front of the laboratory.

ASELL Laboratory Program Evaluation (ALPE) Survey

Name of Laboratory Course Date

This laboratory course is being evaluated as part of a project called “Advancing Science by Enhancing Learning in the Laboratory (ASELL)” An important part of the project involves collecting feedback on students’ experience of various laboratory programs, which is the purpose of this survey. Your responses are anonymous, and participation is voluntary. Put your responses under ANSWERS on the right hand side of this form. If you feel you cannot answer a particular question, just leave it and go onto the next question. Erase errors thoroughly. Also, the survey is double-sided.

	A	B	C	D	E
SCALE:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

1. The laboratory program helped me to develop my data interpretation skills.
2. The laboratory program helped develop my lab skills.
3. This laboratory program helped me to develop my research skills.
4. I found the laboratory program to be interesting.
5. It was clear to me how the laboratory program was assessed.
6. The learning objectives of this laboratory program were clear to me.
7. Completing this lab program has increased my understanding of [discipline/topic].
8. Sufficient background information was provided to me during this laboratory program.
9. My demonstrators provided effective supervision and guidance throughout the laboratory program.
10. The laboratory/field procedures were clearly explained in the laboratory manual/notes.
11. I can see the relevance of this laboratory program to my [discipline] studies.
12. This laboratory program has enabled me to apply what I have learned in [discipline]
13. The laboratory program helped me to develop teamwork skills.
14. The laboratory program helped me develop my communication skills (written or oral).
15. The laboratory program provided me with the opportunity to take responsibility for my own learning.
16. The knowledge and skills I have learnt elsewhere have been useful in this laboratory program.
17. This laboratory program has developed my ethical awareness.
18. I found the total workload in this laboratory program (pre-work, lab work, write-up) appropriate.
19. Please rate the overall learning experience that this laboratory program provided. (A = outstanding; B = good; C = average; D = poor; E = abysmal)

Please turn over and complete the additional questions on the back of this form.

20. What were the good experiments in this program? Why?

21. What were the poor experiments in this program? Why?

22. What aspects of the lab program need improvement and what changes would you suggest?

23. Please provide any additional comments about this lab program that you wish.

Please place this survey in the box at the front of the laboratory.

Name of Experiment **.** **Date**

Please circle: **Staff** **Student**

You have just completed this experiment as part of an ASELL workshop. An important part of this workshop process involves collecting feedback on your experience of the exercise to provide to the submitter of the experiment. Your responses are anonymous. Put your responses under ANSWERS on the right hand side of this form. If you feel you cannot answer a particular question, just leave it and go onto the next question. Erase errors thoroughly. Please note that the scale below should be used for ***only*** questions 1 to 12, as 13 and 14 have separate scales. Also, the survey is double-sided.

	A	B	C	D	E
SCALE:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

1. I expect that completing the experiment will effectively help students to develop their laboratory/practical skills.
2. I expect that completing the experiment will effectively help students to develop their theoretical and conceptual knowledge
3. I expect that completing the experiment will effectively help students to develop their thinking and other generic skills.
4. I expect that this experiment will allow students to learn or practice data interpretation skills.
5. I expect that students will find this experiment interesting.
6. Useful assessment criteria are clearly stated.
7. I expect that the students will find the learning objectives of this experiment to be clear.
8. I believe that students will increase their understand of [discipline] by completing this experiment.
9. Sufficient background information, of an appropriate standard, is provided in the introduction.
10. I believe that the laboratory notes, when supported with guidance from demonstrators and other resources, will provide sufficient support for students as they learn.
11. The experiment requires students to participate as active learners.
12. I believe that the students will see relevance of this experiment to their [discipline] studies.
13. Completing this experiment will improve the teamwork skills of the students.
14. The experiment provides students with opportunities to take responsibility for their own learning.

FOR EACH OF THE NEXT TWO QUESTIONS, USE THE SEPARATE SCALES INDICATED

15. The amount of time available for students to complete this experiment is:
    A = 'way too much' B = 'too much' C = 'about right' D = 'not enough' E = 'nowhere near enough'
16. Overall, as a learning experience, I would rate this experiment as:
    A = 'outstanding' **B** = 'very valuable' **C** = 'worthwhile' **D** = 'of little value' **E** = 'worthless'

Please turn over and complete the additional questions on the back of this form.

15. What are the strengths of the experiment?

16. What are the weaknesses of the experiment?

17. What is/are the main lesson(s) to be learnt from the experiment?

18. What improvements can you suggest for the experiment?

19. Please provide any additional comments on this experiment here.

Please place this survey in the box at the front of the laboratory.

Workshop Evaluation

Please circle if you are a STAFF or a STUDENT delegate.

In this questionnaire we are seeking information about your experience at this workshop as an overall experience. If you feel that you cannot answer a particular question, leave it and go on to the next question.

CODE: A = Strongly Agree; B = Agree; C = Neutral; D = Disagree; E = Strongly Disagree

Q1: The ASELL workshop offers a useful means to improve students learning in laboratory exercises
Q2: Participating in the ASELL workshop has increased my understanding of educational issues
Q3: Participation in the ASELL workshop has been a valuable experience for me
Q4: The design of laboratory exercises involves more than I had previously realised
Q5: Academic staff are more interested in laboratory learning than I had previously realised
Q6: Laboratory exercises are intended to teach more than I had previously realised
Q7: I intend to use the ASELL educational template to evaluate other experiments running at my University
Q8: I would use the ASELL educational template when designing a new laboratory exercise
Q9: Participation in the ASELL workshop has reminded me of what it is like to be a student
Q10: I now have a greater understanding of the importance of theoretical and conceptual knowledge development in laboratory exercises
Q11: I now have a greater understanding of the importance of scientific and practical skills development in laboratory exercises
Q12: I now have a greater understanding of the importance of thinking skills development in laboratory exercises
Q13: I now have a greater understanding of the importance of generic skills development in laboratory exercises

Please turn over and complete the additional questions on the back of this form.

What did you find to be the most valuable aspect of the ASELL workshop? Why?
What area of the workshop do you think most needs to be improved? What improvements would you suggest?
What was the thing at the workshop which you found most surprising?
Please provide any additional comments on the workshop here

Please place this survey in the box at the front of the laboratory.

Staff Survey

Please circle answers to the following questions:

A.	**You are ...**		**Staff**	**Student**
B.	**Your Discipline**	**Biology**	**Chemistry**	**Physics**
C.	**Have you previously heard of ASELL (or ACELL)?**		**Yes**	**No**
D.	**Have you attended an ASELL/ACELL seminar previously?**		**Yes**	**No**

ASELL regularly surveys students about their laboratory learning experience, using an instrument that we call the ASELL Student Learning Experience (ASLE) survey.

The final question on the ASLE survey probes the students' overall perception of their learning experience in the experiment:

> Overall, as a learning experience, I would rate this experiment as:
>
> **A** = 'outstanding' **B** = 'very valuable' **C** = 'worthwhile' **D** = 'of little value' **E** = 'worthless'

Consider the other 12 ASLE survey questions below.

- Please indicate which four of the questions below you think would correlate *most strongly* with the "overall" ASLE survey question above by ticking the "YES" box.
- Please indicate which four of the questions below you think would correlate *least strongly* with the "overall" ASLE survey question above by ticking the "NO" box.

ASLE questions	**YES** correlates	**NO** does not correlate
1. This experiment helped me to develop my data interpretation skills		
2. This experiment helped me to develop my laboratory skills		
3. I found this to be an interesting experiment		
4. It was clear to me how this laboratory exercise would be assessed		
5. It was clear to me what I was expected to learn from completing this experiment		
6. Completing this experiment has increased my understanding of physics		
7. Sufficient background information, of an appropriate standard, is provided in the introduction . .		
8. The demonstrators offered effective supervision and guidance		
9. The experimental procedure was clearly explained in the lab manual or notes		
10. I can see the relevance of this experiment to my physics studies		
11. Working in a team to complete this experiment was beneficial		
12. The experiment provided me with the opportunity to take responsibility for my own learning. . .		

Appendix 2: ASELL Educational Template Resources

ASELL Educational Template

Section 1 – Summary of the Experiment

1.1 Experiment Title

Insert title here

1.2 Introduction and Description of the Experiment

Insert summary here – think of this section as a draft of the introduction to the paper that will ultimately be sent for review.

Section 1 of your paper will be based on the responses to the headings below. However, it may be appropriate in the paper for you to re-arrange or omit some of this information.

1.3 Reasons for Submission

Insert information about why you believe the experiment is a good learning experience for students. This information may be opinion or anecdotal – it addresses why you believe the experiment should be tested, and so does not need support from evidence of the students' experience.

1.4 Experiment Aims and Objectives

Insert information about the experiment aims, relevance, and objectives here

1.5 Level of the Experiment

Insert level (or levels) here – if multiple levels, indicate any differences in the experiment for different levels

1.6 Keyword Descriptions of the Experiment

[Discipline] Domain: Insert at most two keywords here
Specific Descriptors: Insert at most six keywords here

1.7 Course Context and Students' Required Knowledge and Skills

Insert course context description here

Insert description of knowledge and skill requirements here

1.8 Time Required to Complete

Prior to Lab: Insert time here
In Laboratory: Insert time here
After Laboratory: Insert time here

1.9 Authors of Educational Analysis

Name, Institution, E-mail, Telephone, Fax

1.10 Experiment History

Insert details of experiment history here

Insert details of submission here

1.11 Any Other Comments

Insert any other comments here – this might be a good place to include information about potential extensions to the experiment, for example.

1.12 References

Insert any references here

Section 2 – Educational Analysis

Note: Starred outcomes are those that are the principal focus of the exercise. Non-starred outcomes may either be less important, or be outcomes which could be the focus of the experiment if it were modified. Please restrict yourself to no more than 10 outcomes, with no more than 5 starred, and include at least one outcome in each section.

Learning Outcomes		**Process**	**Indicators**
What will students learn?		**How will students learn it?**	*How will staff* ***and*** *students know that the students have achieved the learning outcomes?*

2.1 Theoretical and Conceptual Knowledge

2.2 Scientific and Practical Skills

2.3 Thinking Skills and Generic Attributes

Section 3 – Student Learning Experience

This section will be completed only after the experiment has been tested at a workshop, modified (if necessary), and then run at the submitting institution during semester. ASELL will be responsible for the data collection, and will ensure that all necessary ethics procedures are completed, so that student feedback data may be published. The submitting authors responsible for providing a description of the learning experience based on those data. Data that will be available will come from three surveys:

Workshop survey A, which covers workshop delegates experiences of the experiment itself;
Workshop survey B, which concerns the educational analysis carried out in section 2; and,
Students' in semester evaluation of the experiment.

The ASELL Guidelines and Procedures Document and the ASELL Peer Review Criteria provide information on the data and analysis required in this section.

Section 4 – Documentation

Please provide details of the documentation provided with this submission, under the following headings:

4.1 Student Notes

Insert details, such as file names, here

4.2 Demonstrator Notes

Insert details, such as file names, here

4.3 Technical Notes

Insert details, such as file names, here

4.4 Hazard / Risk Assessment

Insert details, such as file names, here

4.5 *Journal Manuscript*

Insert details, such as file names, here

4.6 Workshop Notes

Insert details, such as file names, here

4.7 Any Additional Documentation

Insert details, such as file names, here

Information about the ASELL Educational Template

The ASELL project aims to improve the quality of learning in undergraduate chemistry laboratories by making available student-tested, peer-reviewed experiments which are both chemically and educationally sound. This document provides information and guidance to assist people when completing the *ASELL Educational Template*. The Educational Template sets out the educational objectives of experiments included in the ASELL database and serves two purposes. The first is as a guide to submitters of an experiment for reflection on the learning objectives of their experiment. The second is that it provides users of the ASELL database with evidence that the experiments are high quality learning resources. Please note that this information sheet is intended as a guide for submitters preparing an Educational Template, and it does not replace the overall Guidelines and Procedures document.

The template is divided into four sections, which present:
(1) a general summary;
(2) an analysis of the educational objectives;
(3) student experiences; and,
(4) documentation.
Information and guidance to assist in responding to each of these sections is provided below.

Please note that the objectives and methods described in the template and accompanying documentation are not intended to be prescriptive. When completing the template, it may be necessary for a submitter to modify or omit parts in order to best suit a particular experiment. Similarly, users of the database should adapt ASELL experiments to suit particular teaching contexts and resources. Users may also wish to adopt teaching approaches and strategies described in these templates for use with other experiments and other undergraduate laboratory teaching. Submitters of experiments should take this into account and present options, alternatives and extensions wherever possible and appropriate.

The ASELL submission process involves several stages, the first of which involves testing the experiment away from the submitting institution. Template sections (1), (2), and (4) must be completed prior to an experiment being tested at an ASELL workshop, or at an institution other than the submitting institution. After the workshop, ASELL will organise for the collection of student feedback data at the submitting institution, which will be provided to the submitters once the teaching semester is complete; these data will be used when completing section (3). Sections (1) to (4) must be fully completed and peer reviewed (against the peer review criteria available in the document library of the ASELL website) prior to an experiment being included in the ASELL database.

SUMMARY: This section provides a general overview of the experiment, which allows database users to quickly determine whether an experiment is suitable for their use.

EDUCATIONAL ANALYSIS: The second section is a table that provides a clear description of the intended learning outcomes (i.e., what you anticipate that a student will learn by undertaking this experiment), a description of how this learning will be achieved and a description of how this learning can be monitored.

The *learning outcomes* cover theoretical understanding as well as skills, and provide the basis for the learning outcomes that should be included in the student notes. The description of *how this learning will be achieved* contributes to both demonstrator notes and student notes. This section provides the basis for identifying what teachers and learners have to actually do in the laboratory and in associated work, such as reports, in order for students to learn what is intended. The final section of the table describing *how the learning can be monitored* provides the basis for indicators that could be used by demonstrators and students to monitor the learning achievement of learning outcomes.

STUDENT LEARNING EXPERIENCE: The third section presents evidence from students regarding the quality of their learning experiences in this laboratory. Both five point (Likert) scale and open answer data should be included in this analysis. These data allow for an evidence-based discussion of the extent to which the outcomes described in the educational analysis are reflected in the students' experiences of the experiment.

DOCUMENTATION: The fourth section contains the student, demonstrator and technical notes for the experiment. Intended learning outcomes and assessment criteria should be clearly stated in both the student and demonstrator notes.

Section 1 – Summary of the Experiment
The title of the experiment in section (1.1) should be concise, but also descriptive. It is preferable to avoid titles which are so broad that they could be applied to a large number of different experiments – a title such as 'Reduction and Oxidation Processes', for example, could refer to experiments which investigate the activity series, Galvanic cells, corrosion, or electrorefining, and so should be changed to something more descriptive

Section (1.2) should provide a short (one paragraph) summary of the experiment, as well as a fairly short (one to two paragraph) description of the experiments' aims, its relevance to students, and possibly some comment on the reasons for its effectiveness as a learning tool. Depending on the reasons for submission (section 1.3), it may be appropriate to leave such comment out of section (1.2). Section (1.3) was added to the template following the major ASELL workshop in February 2006, as workshop delegates wanted to see an explicit comment as to why the submitter wanted to put the particular experiment through the testing process. As such, the reasons may be anecdotal or peculiar to a particular institution.

Section (1.4) should provide a short (one to two paragraph) summary of the aims and objectives. Some experiments can be used to promote multiple different aims, and are tailored to a particular approach. This section should focus on the approach as it is adopted at the home institution. There is opportunity to outline possible extensions or alternative emphases elsewhere in the template.

Section (1.5) should indicate the level (first year undergraduate, second year undergraduate, etc.) of the experiment. If the experiment is appropriate for more than one level, but requires some modifications for each, then these should be (briefly) indicated here.

The keyword descriptors in section (1.6) will be used within the ASELL database to assist in searching for experiments. At most two chemistry domain keywords should be chosen from the following list:
Analytical chemistry
General chemistry
Organic chemistry
Theoretical chemistry
Biological chemistry
Inorganic chemistry
Physical chemistry

You may include up to six specific descriptor keywords – these may be relative general (such as synthesis, kinetics, or electrochemistry) or quite specific (such as aldol condensation, or BZ reaction). These keywords will be used to generate a master list for use with ASELL experiments in the future.

For the disciplines of biology and physics, is not yet available, however, it is in the process of being prepared. Suggestions of keywords are also welcome.

Section (1.7) should include a description (one to two paragraphs) of the relationship of the experiment to the course being undertaken by the students. A description of the knowledge and skills students require in order to complete the experiment is also included here. The idea is to allow someone considering adopting the experiment to have a concise summary of the prior knowledge necessary for the experiment, so that its suitability to their own course contexts can be easily considered. Estimations of time students will require before, during, and after the experiment are included in section (1.8).

Full details for all authors are listed in section (1.9). These are the authors of the educational analysis, and submitted the experiment to the ASELL database; no claim of authorship of the experiment is made in section (1.9). However, by submitting the experiment, these authors are warranting that the experimental materials (student notes, etc.) will be made available for others to use and modify. As such, they are undertaking that their department will not assert copyright over these materials.

Section (1.10) describes the history of the experiment. All possible effort should be made to acknowledge and appropriately reference the original sources of the experiment, and to recognise the contributions that have been made to its development. If the origin of the experiment is unknown, this should be stated. The details of the basis on which the submission to ASELL is being made should also be described here. For example, if an experiment has a long history at a particular institutions, a statement such as
This experiment has a long history in DEPARTMENT at UNIVERSITY; whilst the authors listed in section (1.9) are responsible for the educational analysis of this experiment, their submission of it to ASELL is done on behalf of all academic staff
should be included. If the submitters developed the experiment themselves, then a statement such as:

This experiment was developed by the authors listed in section (1.7), and has been published in the *Journal of Chemical Education*[REF]; as such, this submission is made by them in their own right
might be appropriate. Submitters should not feel bound to use this form of words to describe the basis for the submission; however, a clear statement of that basis is required.

Section (1.11) provides the submitter with the opportunity to make any further comment that they believe are necessary or desirable, and which do not fit into any of the above sections. This might include potential extensions to the experiment, or different implementations, for example. References should be included in section (1.12), along the lines of the APA author-date style, which includes full titles – this is done to make the reference list more informative. Some examples of appropriately formatted references are provided below:

McMurry, J. (1992). *Organic Chemistry.* (3rd ed.). Belmont, CA: Brooks / Cole

Horton, C. (2001). *Student Preconceptions and Misconceptions in Chemistry.*

http://daisley.net/hellevator/misconceptions/misconceptions.pdf

Paris, S. G. and Turner, J. C. (1994) Situated motivation. In P. R. Pintrich, D. R. Brown, and C. E. Weinstein (Eds.). *Student Motivation, Cognition and Learning: Essays in Honour of Wilbert J. McKeachie* (pp. 213 – 237). Hillsdale, NJ: Erlbaum.

Wickman, P. O. (2004). The practical epistemologies of the classroom: A study of laboratory work. *Science Education,* **88**, 325 – 344.

Section 2 – Educational Analysis

To carry out the educational analysis, it is necessary to document what are the expected learning outcomes, the process by which those outcomes are achieved, and how the extent to which the learning outcomes have been achieved will be determined. This last point covers not only how staff will assess students' learning, but also how the students will be able to judge their progress for themselves. If students are to base such a judgement on assessment results, they would require detailed and individual feedback (from a marking pro-forma with areas of strength and weakness indicated, for example); numerical results are not a sufficient basis for making such a judgement.

The learning outcomes are divided into three categories: *Theoretical and Conceptual Knowledge, Scientific and Practical Skills,* and *Thinking Skills and Generic Attributes.* There is significant overlap between these categories, and it is not critical into which category an anticipated outcome is placed – the important issue is that all the principal learning outcomes are recognised and described. Careful thought should be given to the thinking skills area of the third category, as the development and practice of thinking skills are frequently fundamental to the analysis of laboratory results, and it is easy for these to be overlooked.

No more than ten outcomes may be listed in this section, of which up to five may be marked with an asterisk (*) to indicate that they are the most important outcomes relating to the experiment as it is implemented in its home institution. Non-asterisked outcome(s) could conceivably be ones that might be emphasised if the experiment were to be re-cast, but which are not emphasised in its present formulation. It is generally expected that outcomes will be listed in all three categories, but this is not a formal requirement. The template may be modified to add additional rows to any section, should this be necessary.

Guidelines for the learning outcomes are provided below. It is important to note that these guidelines do not constitute an exhaustive list, and nor is there any requirement that some response be provided in every category – the template is not intended to be prescriptive, but rather to facilitate the educational analysis being completed.

Theoretical and Conceptual Knowledge:

Theoretical and conceptual knowledge deals with the intended academic learning outcomes of the experiment and includes (but is not limited to) that which may be described as:

backing up, clarifying or extending the knowledge that students may gain from lectures, tutorials, self-study and such like;

being "integrated to lectures";

"clarifying complicated theory"; and,

allowing the student to "see the implications of the experiment or theory".

Scientific and Practical Skills:

Scientific skills include (but are not limited to) the:

ability to observe and record, and report, using appropriate scientific language;

ability to collate, correlate, display, analyse and report observations;

ability to apply deduction and induction;

application of appropriate statistical tests;

performance of appropriate error analysis; and,

ability to form hypotheses and test them experimentally.
Examples of practical skills include (but are not limited to) the:
ability to choose and use appropriate wet and dry chemical methods;
understanding and operation of instrumentation;
manipulation and presentation of data (plotting, spreadsheeting, etc); and,
ability to present reports in appropriate formats.
Consideration should be given to these skills that can be transferred to other academic domains, or to the non-academic environment. There may be considerable overlap with *Thinking Skills and Generic Attributes*, as many *Scientific and Practical Skills* are domain-focused examples of generic or thinking skills.

Thinking Skills:
Thinking skills include (but are not limited to):
Critical Analysis: evaluating relevance and relating knowledge to the real world;
Problem Solving: ability to apply problem solving in familiar and unfamiliar situations, and to display the capability of rigorous and independent thinking;
Critique: suggesting modifications and improvements to procedures;
Self-Management: the ability to plan and organise self-directed study and work activities, including choosing appropriate experimental investigations;
Monitoring: the ability to monitor progress towards a goal, and to modify activities or adjust one's behaviour tin response; and,
Self-Assessment: the ability to account for decisions and be realistic evaluators of results and one's own performance, and to reflect on where improvements can be made.

Generic Attributes:
Generic attributes include (but are not limited to):
Academic Culture: having an appreciation of the requirements and characteristics of scholarship and research including developing a respect for truth and intellectual integrity, and for the ethics of scholarship;
Communication Skills: be able to identify, access, organise and communicate information in both written and oral forms, and to demonstrate understanding of complex texts and data typical of the discipline of study by communicating that understanding in a manner appropriate to the target audience;
Working with Others: in pairs and in larger teams, understanding and responding to task demands and working effectively to achieve a shared goal, coping with set backs;
Leadership: skill of leadership in small groups;
Technology and Technical Skills (including computer skills): the ability to use appropriate technologies for the achievement of undertakings inside and outside of the university circumstance;
Numeracy: applying appropriate statistical tests and judging the accuracy of conclusions drawn from statistics;
Ethical Behaviour: acknowledge their personal responsibility for their own value judgements and their ethical behaviour towards others;
Life-Long Learning: the capacity for and a commitment to life-long learning.

Section 3 – Student Learning Experience
This section will be completed only after the experiment has been tested at a workshop, or at an institution other than the submitting institution, modified (if necessary), and then run at the submitting institution during semester. ASELL will be responsible for the data collection, and will ensure that all necessary ethics procedures are completed, so that student feedback data may be published. Data that will be available will come from three surveys:
Workshop survey A, which covers workshop delegates experiences of the experiment;
Workshop survey B, which concerns the educational analysis carried out in section 2; and,

Students' in semester evaluation of the experiment.

Whilst ASELL will carry out some simple analysis of these data, the submitting author(s) will be responsible for providing a description of the learning experience based on these data. Areas which could be discussed in this section include (but are not limited to):
Comparison of the evaluations of the experiment provided by workshop delegates and by students during semester;
The overall value of the experiment as a learning experience;
Modifications made to the experiment in response to feedback data;
Strengths and weaknesses of the experiment, with some interpretation of why this might be the case;
Qualitative feedback data from students concerning
reasons they enjoyed (or did not enjoy) the experiment; and,
what they believe was the main lesson to be learnt.

Section 4 – Documentation
Guidelines for the preparation of electronic documents to be included with your submission are as follows:
Acceptable documents are those that are most commonly editable, e.g., MS Word, WordPerfect, RTF. The final versions will be uploaded to the database in both MS Word and PDF file formats;
Please include a margin of at least 2 cm in your documents;
If possible, please include with the final submission PDF versions of the documents **in addition** to the editable forms, as this will help us resolve issues of fonts, equations and images, which can cause problems when moving between computers;
Non-embedded images files should be JPEG, GIF or TIFF format;
Chemical structures may be in CS ChemDraw or MDL ISIS compatible formats.

The documents required are as follows:

Student Notes, section (4.1), are the notes as they are given to students, including pre/post labs, reference material, etc. Student notes should include a statement of intended learning outcomes and assessment criteria.

Demonstrator Notes, section (4.2), should be more than simply a list of expected results. They should include sufficient detail so that demonstrators can:
identify common obstacles encountered by students in completing the experiment, and thus be able to "trouble-shoot" the experiment;
communicate to students important aspects of the experiment (concepts, observations, etc);
identify the time line for completion of the experiment and help students maintain an acceptable work pace;
compare students results with the "accepted" result (through the provision of sample data – examples of raw numerical data and plots, spectra, spreadsheets, etc). Whilst it is recognised that some inquiry and discovery based exercises may not lead to predictable results, demonstrators do still need some guidance on how to judge whether students are coming to reasonable conclusions; and
understand the assessment criteria and help students achieve the required goals.

Technical Notes, section (4.3), should include enough information for academic and technical staff to set-up and run the experiment without recourse to personal contact with the submitter of the experiment. Information might include:
Parameters required for common equipment (e.g., resolution of FT-IR spectrometers, temperature control requirements, etc)
Name, supplier and approximate cost of uncommon equipment and chemicals
Set-up and operation procedures (Standard Operating Procedures, if applicable)

Hints and tips on less obvious aspects of the experiment and apparatus
Safety issues
Diagrams and / or photographs of unusual experimental setups

Hazard / Risk Assessment, section (4.4), is a copy of whatever documentation is required by the home institution.

Journal Manuscript, section (4.5), is only required for the final submission.

Workshop Notes, section (4.6), relate only to the first phase of the evaluation process, and will not be required for many experiments. If the full version of an experiment takes longer to run than the time available at a workshop, then workshop notes will explain how the experiment will be tested at a workshop. This may be as simple as a statement identifying parts of the experiment, described in the student notes, which will be omitted. It might be notes to the effect that a certain compound, which students would normally prepare, will be provided. Alternatively, it might be a full set of notes for an exercise or exercises which encapsulate the essence of the submitted experiment. Submitters should carefully consider how best to represent their experiment, if a shortened version will be tested at a workshop. The educational analysis in section (2) is based on the full, submitted experiment, and not on the shortened version; it is therefore important that the shortened version represent the experiment sufficiently well for workshop delegates to be able to evaluate the educational analysis.

Additional Documentation, section (4.7), will also be unnecessary for many experiments – inclusion of such documents will be at the discretion of submitters. Such documents might include Excel spreadsheets to be used in data analysis or information on non-compulsory extension activities which students might choose to undertake. In fact, anything which a submitter might wish to provide, but which would not be included with student, demonstrator, or technical notes, could be included here.

Appendix 3: Workshop Materials

List of participants – University of Adelaide

Name	Organisation	Discipline Workshop
Angela Arlotta	University of Sydney	Biology
Ragbir Bhathal	University of Western Sydney	Physics
Warwick Belcher	University of Newcastle	Chemistry
Stephen Best	University of Melbourne	Chemistry
Stephen Bigger	Victoria University	Deans Workshop
Adam Blanch	Flinders University	Physics
Tania Blanksby	La Trobe University	Biology
Simon Boman	University of Queensland	Chemistry
Adam Brotchie	University of Melbourne	Chemistry
Sam Buckberry	Flinders University	Biology
Mark Buntine	Curtin University	ASELL Director
Karen Burke da Silva	Flinders University	ASELL Director
Robert Burns	University of Newcastle	Chemistry
Blake Cochran	University of Western Sydney	Biology
Perran Cook	Monash University	Chemistry
Michelle Coulson	University of Adelaide	Biology
Anang Diah	University of Newcastle	Chemistry
Alana Digby	University of Sydney	Biology
Adrian Dinsdale	La Trobe University	Biology
Hanna Driessen	Curtin University	Chemistry
Peter Leigh Edwards	University of Adelaide	Physics
Jack Evans	University of Adelaide	Chemistry
Mary Familari	University of Melbourne	Deans Workshop
Jessica Francis-Staite	Flinders University	Physics
Lawrie Gahan	University of Queensland	Deans Workshop
Sheridan Gentili	University of South Australia	Deans Workshop
Helen Georgiou	University of Sydney	Physics
Michael Goddard	Monash University	Biology
Armando Guidote	Ateneo de Manilla University	Chemistry
Dale Hancock	University of Sydney	Chemistry
Pippa Hambling	La Trobe University	Biology

Name	Organisation	Discipline Workshop
Ian Harding	Swinburne University of Technology	Deans Workshop
Bob Hill	University of Adelaide	Deans Workshop
Emily Hoffman	Flinders University	Biology
John Holdsworth	University of Newcastle	Physics
Courtney Hollis	University of Adelaide	Chemistry
David Hoxley	La Trobe University	Physics
Leif Humbert	University of Queensland	Physics
Angie Jarrad	University of Adelaide	Chemistry
Elizabeth Johnson	La Trobe University	Deans Workshop
Soumya Joseph	University of Sydney	Chemistry
Sashi Kant	University of Sydney	Chemistry
Alison Kellow	La Trobe University	Biology
Adam Kessler	Monash University	Chemistry
Eleanor King	University of Adelaide	Physics
Nigel Kuan	University of Sydney	Physics
Tracey Kuit	University of Wollongong	Biology
Warren Lawrance	Flinders University	Deans Workshop
Claire Lenehan	Flinders University	Chemistry
Christine Lindstrøm	University of Sydney	Physics
Michelle Livett	University of Melbourne	Deans Workshop
Nick Li	University of Adelaide	Biology
Kieran Lim	Deakin University	ASELL Director
Anna Lister	La Trobe University	Biology
Andrew MacKinnon	University of Adelaide	Physics
Joel Martens	University of Newcastle	Physics
Elizabeth May	University of Sydney	Biology
Tim McIntyre	University of Queensland	Physics
Ian McCulloch	University of Queensland	Physics
Andre Messina	La Trobe University	Biology
Peter McGee	University of Sydney	Biology
Sydel Michielsen	Curtin University	Physics
Mauro Mocerino	Curtin University	Chemistry
Camille Mucha	La Trobe University	Physics
Anna Murphy	La Trobe University	Biology
Rhys Murphy	Flinders University	Chemistry
Robert Norris	Monash University	Deans Workshop

Name	Organisation	Discipline Workshop
David Ottaway	University of Adelaide	Physics
Alan Payne	Curtin University	Chemistry
Svetlana Petelina	La Trobe University	Physics
Sally Plush	University of South Australia	Deans Workshop
Tara Pukala	University of Adelaide	Chemistry
Simon Pyke	University of Adelaide	ASELL Director
Jamie Quinton	Flinders University	Physics
Gerry Rayner	Monash University	Biology
Ren Xiao-An	University of Adelaide	Biology
John Rice	University of Sydney	Deans Workshop
Justin Read	University of Adelaide	ASELL Team
Lynn Rogers	University of Adelaide	Biology
Ken Sanderson	Flinders University	Biology
Manjula Sharma	University of Sydney	ASELL Director
Philip Sharpe	University of Queensland	Chemistry
Jason Siddaway	La Trobe University	Physics
Salim Siddiqui	Curtin University	Physics
Ashley Slattery	Flinders University	Physics
Amanda Smith	University of Queensland	Physics
Daniel Southam	Curtin University	Chemistry
Christopher Sumby	University of Adelaide	Chemistry
Richard Tarrant	University of Sydney	Physics
Guy Travers	Curtin University	Chemistry
Cristina Varsavsky	Monash University	Deans Workshop
Sioe See Volaric	University of Melbourne	Chemistry
Daniel Veen	Curtin University	Physics
Jo Ward	Curtin University	Deans Workshop
Helen Williams	University of Sydney	Chemistry
Natalie Williamson	University of Adelaide	Chemistry
Alexandra Yeung	University of Sydney	ASELL Associate Director
Jeanne Young	Flinders University	Biology
Jodie Young	La Trobe University	Biology
Mario Zadnik	Curtin University	Physics
Sara Zadnik	Curtin University	Chemistry
Diana Zaleta-Pinet	University of Newcastle	Chemistry

Workshop program – University of Adelaide

Tuesday 6 April 2010		**Chemistry Courtyard** 1100-1400		**Rennie Lecture Theatre** 1400-1700	1700-1730		**Eclipse Function Room (Level 4 Union House)** 1800-late	
		Check-in at accommodation in the morning. **Registration from 11am.** Opportunity to set up for Wednesday laboratory sessions. Light lunch 1300-1400		Welcome, ASELL aims & processes. Completing the educational template. Safety Induction.	Set up or free time		Welcome Mixer	
Wednesday 7 April 2010	**Rennie Lecture Theatre** 0900-1000	**Various#** 1000-1300	**Various^** 1300-1400	**Various#** 1400-1700	1700-1730		**Various*** 1800-1900	**Eclipse Function Room (Level 4 Union House)** 1900-late
	Panel discussion	Hands-on Experimental session 1	Lunch	Hands-on Experimental session 2	Clean up and set up		Review of experiments	Dinner and informal discussion
Thursday 8 April 2010	**Macbeth Lecture Theatre (Badger Bldg ground floor)** 0900-1000	**Various#** 1000-1300	**Various^** 1300-1400	**Various#** 1400-1700	1700-1730		**Various*** 1730-1830	**Ciao Restaurant** 1900-late
	Deans Workshop Begins: Welcome, ASELL aims & processes. ***Registration from 8:30am***	Hands-on Experimental session 3	Lunch	Hands-on Experimental session 4, plus clean up	Clean up		Review of experiments	Workshop Banquet and informal discussion
Friday 9 April 2010	**Macbeth Lecture Theatre (Badger Bldg ground floor)** 0900-1000	**Rennie Lecture Theatre** 1000-1300	**Chemistry Courtyard** 1300-1400	**Macbeth Lecture Theatre (Badger Bldg ground floor)** 1400-1700				
	Deans Discussion (TBC)	Workshop on how to use collected data. *4-day workshop CLOSE*	Lunch	**Deans Workshop** discussion and CLOSE				

 # Biology: Molecular Life Sciences Building, Lab G04 (mornings)/G08 (afternoons); **Chemistry:** Badger Lab G10 (Wednesday)/Johnson Lab 106 (Thursday); **Physics:** Bragg Laboratories (See Experiment schedule for exact locations)

^ Morning tea/lunch/afternoon tea will be available at the Biology/Chemistry/Physics locations.

*** Biology:** Margaret Murray Room [Level 4 Union House]; **Chemistry:** Harry Medlin Room (North) [Level 4 Union House]; **Physics:** Harry Medlin Room (South) [Level 4 Union House]

List of experiments – University of Adelaide

Biology Experiments

Name of Experiment	Submitter	Institution
The Polymerase Chain Reaction	Michelle Coulson	University of Adelaide
Sephadex Chromatography.	Lynn Rogers	University of Adelaide
Brain Dissection	Ken Sanderson	Flinders University
Mollusc Oxygen Consumption Prac	Jeanne Young	Flinders University
Extracting DNA from strawberries.	Tania Blanksby	La Trobe University
The Structure & Function of Leaves.	Adrian Dinsdale	La Trobe University
From Water to Land – Algae, Mosses & Ferns	Alison Kellow	La Trobe University
Cytogenetics.	Jodie Young	La Trobe University
Amylase activity In Germinating Barley	Gerry Rayner	Monash University
An Investigation of the Distribution of Airborne Fungi in the Sydney Basin.	Peter McGee	The University of Sydney
Respiration in Yeast	Elizabeth May	The University of Sydney
Proteins & Enzymes	Tracey Kuit	University of Wollongong

Chemistry Experiments

Name of Experiment	Submitter	Institution
Ester Hydrolysis and Acid Identification	Tara Pukala	University of Adelaide
Synthesis of virstatin, a virulence inhibitor of vibrio cholera	Christopher Sumby	University of Adelaide
Quantitative Techniques	Natalie Williamson	University of Adelaide
Determination of Vanillin in Imitation Vanilla Essence	Mauro Mocerino	Curtin University
Synthesis of 6-Methylazulene	Alan Payne	Curtin University
Anion Incorporation into Layered Solids	Daniel Southam	Curtin University
Buffer Solutions	Claire Lenehan	Flinders University
Determination of Alkalinity, tCO_2, and pCO_2 in the waters of the Yarra Estuary using in pH Measurements and a Modified Gran Titration	Perran Cook	Monash University
Synthesis, Characterisation and Linkage Isomerism of Photoactive *cis-bis*(2,2'-bipyridine) chloro(dimethlysulfoxide)-ruthenium(II) hexafluorophosphate [Ru(bpy)2Cl(DMSO)](PF_6)	Stephen Best and Sioe See Volaric	The University of Melbourne
Preparation, Distillation and Spectroscopic Identification of 2-choloro-2-methylpropane	Warwick Belcher	The University of Newcastle
Chemical Equilibrium	Robert Burns	The University of Newcastle
Protein Purification	Dale Hancock	University of Sydney
Glucose Enzyme-Linked Metabolite Assay	Sashi Kant	University of Sydney

Physics Experiments

Name of Experiment	Submitter	Institution
Conservation of Energy	Andrew MacKinnon	The University of Adelaide
Thin Lenses	David Ottaway	The University of Adelaide
Radioactivity Measurements	Salim Siddiqui	Curtin University
An Investigation of a Simple Pendulum	Marjan Zadnik	Curtin University
Circular Polarisation with Quarter and Half Wave Plates	Jamie Quinton	Flinders University
Fabry-Perot Etalons	Jamie Quinton	Flinders University
The Ballistic Pendulum	David Hoxley	La Trobe University
UV Radiation Experiment	Svetlana Petelina	La Trobe University
Electromagnetic Induction and Transformers	John Holdsworth	The University of Newcastle
Build a Telescope	Tim McIntyre	The University of Queensland
Charge and Electric Forces	Ian McCulloch	The University of Queensland
Solar Cells	Chrsitine Lindstrøm	The University of Sydney
The Oscilloscope	Richard Tarrant	The University of Sydney
Acceleration Due to Gravity	Ragbir Bhathal	The University of Western Sydney

ASELL Curtin University Showcase

Monday 11th October 2010

Venue: Curtin University, Resources and Chemistry Precinct, Building 500, Level I Exhibition Space.

1:00pm	***Registration with light lunch served***
2:00pm	***Welcome*** **Jo Ward**
	Introduction to ASELL (**CHAIR:** Kieran Lim)
2:10 – 3:10	**Simon Pyke** *The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter*
	ASELL Chemistry at Curtin University
3:10 – 3:50	**Daniel Southam** *Not all experiments are created equal: ASELL evaluation of a first year laboratory program*
3:50 - 4:10	***Afternoon Tea***
	ASELL Physics at Curtin University (**CHAIR**: Manju Sharma)
4:10 – 4:30	**Salim Siddiqui** *Applying the ASELL Framework for Improvement of a First Year Physics Laboratory Program*
4:30 – 4:50	**Marjan Zadnik** *The "Simple Pendulum" Experiment: Not So Simple*
4:50 – 5:10	**Mark Buntine** *ASELL – The Way Forward: What Does it Mean for WA Universities?*
5:10 – 5:50	***Discussion*** **facilitated by Mark Buntine**
5:50 – 6:00	***Close*** **Jo Ward**

List of participants – Curtin University

First Name	Surname	Position/Department
Faisal	Anwar	Dept of Civil Engineering
Stuart	Bailey	Chemistry
David	Brown	Chemistry
Mark	Buntine	HOD - Chemistry
Karen	Burke Da Silva	Flinders University - School of Biological Sciences
Christine	Cooper	E&A
Geoffrey	Crisp	The University of Adelaide - Centre for Learning and Professional
Vaille	Dawson	Science & Maths Education Centre
Michaele	Gardiner	School of Biomedical Sciences
Mark	Gibberd	HOD
Phil	Groom	E&A
Christine	Howitt	Science & Maths Education Centre
Damian	Laird	Murdoch
Glenda	Leslie	AISWA
Simon	Lewis	Chemistry
Kieran	Lim	Deakin University - School of Life and Environmental Sciences
Euan	Lindsay	Mechanical Eng
Sue	Low	E&A
Ian	McArthur	UWA - HOD - Physics
Mauro	Mocerino	Chemistry
Robert	Norris	Monash University - Dean, Faculty of Science
Mark	Ogden	Chemistry
Jonathan	Paxman	Dept of Mechanical Engineering
Simon	Pyke	The University of Adelaide - School of Chemistry and Physics
Priyantha (Ranjan)	Sarukkalige	Dept of Civil Engineering
Manjula	Sharma	The University of Sydney - School of Physics
Salim	Siddiqui	Applied Physics
Jane	Sneesby	E&A
Daniel	Southam	Chemistry
Mark	Spackman	UWA - Chair, Discipline of Chemistry
Mike	Tan	Chemistry
Chris	Taylor	Chemistry
Magda	Wajrak	ECU - School of Natural Sciences
Jo	Ward	Dean of Sciences/ HOS
Shelley	Yeo	Dean of Teaching and Learning
Alexandra	Yeung	The University of Adelaide - School of Chemistry
Marjan	Zadnik	Applied Physics
Sara	Zadnik	Student - Chemistry

The Advancing Science by Enhancing Learning in the Laboratory (ASELL) Project: The Next Chapter

Simon C. Barrie[1], Mark A. Buntine[2], Karen Burke Da Silva[3], Scott H. Kable[4], Kieran F. Lim[5], Simon M. Pyke[6], Manjula D. Sharma[7] and Alexandra Yeung[4]

[1]Institute for Teaching and Learning, The University of Sydney, NSW;
[2]Department of Chemistry, Curtin University, WA
[3]School of Biological Sciences, Flinders University, SA
[4]School of Chemistry, The University of Sydney, NSW
[5]School of Life and Environmental Sciences, Deakin University, VIC
[6]School of Chemistry and Physics, The University of Adelaide, SA
[7]School of Physics, The University of Sydney, NSW

Most researchers agree that the laboratory experience ranks as a significant 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 presentation will provide you with an introduction to ASELL and discuss the current activities of ASELL, the first ASELL science workshop held at the University of Adelaide in April 2010.

Not All Experiments are Created Equal: ASELL Evaluation of a First Year Laboratory Program

Daniel Southam[1], Mauro Mocerino[1], Mark Buntine[1], Marjan Zadnik[2], Salim Saddiqui[2] and Jo Ward[3]

[1]Department of Chemistry, Curtin University, WA
[2]Dept of Imaging and Applied Physics, Curtin University, WA
[3]School of Science, Curtin University, WA

Good laboratory programs that lead to student engagement and motivation are viewed as an essential component of a science course. However, cogent educational arguments for compelling students to undertake laboratories, particularly when science is taught as a service to non-science majors, are poorly communicated to students and service clients alike.

At Curtin the ASELL formalism is being utilised to evaluate the student experience in our first year laboratory program, with the overall aim to improve this experience. ASELL provides a framework for educational assessment of both individual experiments and entire laboratory programs in three disciplines of science; chemistry, physics and biology.

Results from ASELL surveying of Curtin students' attitudes to individual experiments and a semester-long program in first year chemistry will be presented. This evaluation illustrated that the educational validity of some experiments altered between different cohorts of students as a result of their background in chemistry, situational interest or chosen course of study.

These insights have enabled us to assess each experiment and the program as a whole and to define the educational intent and outcomes of a mandatory laboratory program. Likewise, it has allowed us to strongly articulate the laboratory experience with both specific and generic graduate attributes.

Applying the ASELL Framework for Improvement of a First Year Physics Laboratory Program

Salim Siddiqui[1], Daniel Southam[2], Mauro Mocerino[2], Mark Buntine[2], Jo Ward[3] and Marjan Zadnik[1]

[1]Dept of Imaging and Applied Physics, Curtin University, WA
[2]Department of Chemistry, Curtin University, WA
[3]School of Science, Curtin University, WA

Physics 115 is a first-year non-calculus based unit offered to a wide range of students from various disciplines. The unit is taken by about 350 students per year, who have little or no background in physics. One of the assessment components of the unit is laboratory work which involves taking measurements, calculating uncertainties, performing data analysis, interpreting results and submitting formal written reports for assessment. In order to better understand students' views on their laboratory experience, an extensive survey program was initiated by the project Team in Semester 2, 2009. The survey data was analysed to investigate the characteristics of each of the six experiments. The results from the student responses indicated that two of the six experiments, "Simple Pendulum" and "Radioactivity Measurements", needed revision.

In order to obtain further detailed feedback from peers (students and staff from other universities), the two experiments were presented at the ASELL* Workshop held at the University of Adelaide in April 2010. As a result of the feedback from the ASELL Workshop, the "Radioactivity Measurements" experiment was immediately revised and presented to students in May of 2010. At the conclusion of the experiment, students' feedback was once again collected and analysed. We will present the process, and results of the pre- and post-evaluation of this modified experiment, and demonstrate the effectiveness and power of the ASELL framework.

The "Simple Pendulum" Experiment: Not So Simple

Marjan Zadnik[1], Daniel Southam[2], Mauro Mocerino[2], Mark Buntine[2], Jo Ward[3] and Salim Siddiqui[1]

[1]Dept of Imaging and Applied Physics, Curtin University, WA
[2]Dept of Chemistry, Curtin University, WA
[3]School of Science, Curtin University, WA

The Simple Pendulum experiment is one of the ten most widely used experiments in undergraduate physics courses throughout the world. At Curtin it is part of both first year physics units for majors (Physics 101) and for students who have not previously studied physics but are required to do so for other degree programs (Physics 115). When the ASELL methodology was applied to all 6 of the Physics 115 experiments for non-physics majors, two experiments (The Simple Pendulum and Radioactivity Measurements, discussed elsewhere) did not meet the ASELL criteria of being a good learning experience. These two experiments were thus selected for the Adelaide Workshop to undergo peer and student (from other universities) review. As a result of this feedback we became more aware that this experiment is not simple from the students' perspective and indeed very demanding. This talk will discuss the experiment, the feedback obtained from peers, and what we are doing to address these comments.

Appendix 4: Summary of data collected

ASLE

Semester 1, 2010

Institution	Number of academics	Number of surveys distributed
Curtin University (Chemistry)	3 people, 4 experiments	1101
Curtin University (Physics)	2 people, 3 experiment	278
Deakin University (Chemistry)	1 academic, 5 experiments, 2 campuses	???
University of Adelaide (Chemistry)	1 academic, 1 experiment	52
University of Melbourne (Biology)	1 academic, 2 experiment	186
University of Newcastle (Chemistry)	1 academic, 6 experiments	69
University of Queensland (Physics)	1 academic, 2 experiments	About 160
University of Sydney (Biology)	1 academic, 2 experiments	108
University of Sydney (Chemistry)	1 academic, 3 experiments	700
University of Sydney (Physics)	1 academic, 1 experiment	89
University of Western Australia (Chemistry)	1 academic, 2 experiments	321
University of Western Sydney (Physics)	1 academic, 1 experiment	97
University of Wollongong (Biology)	1 academic, 1 experiment	191

Total surveys distributed: 3352

Semester 2, 2010

Institution	Number of academics	Number of surveys distributed
Curtin University (Chemistry)	3 people, 4 experiments	2147
Curtin University (Physics)	3 people, 4 experiments	???
Deakin University (Chemistry)	1 academic, 5 experiments, 2 campuses	???
Flinders University (Physics)	1 academic, 2 experiments	26
La Trobe (Physics)	1 academic, 2 experiment	330
Monash University (Biology)	1 academic, 1 experiment	356
Swinburne University (Biology)	1 academic, 1 experiment	120
University of Adelaide (Physics)	1 academic, 1 experiment	Distributed
University of Sydney (Physics)	1 academic, 2 experiment	327
University of Wollongong (Biology)	1 academic, 1 experiment	250

Total surveys distributed: 3556

ALPE

Semester 2, 2009

Institution	Number of academics	Number of surveys distributed
Curtin University (Chemistry)	3 academic, 7 courses	336
Curtin University (Physics)	3 academic, 3 courses	27
Flinders University (Biology)	1 academic, 1 course	34
Flinders University (Physics)	1 academic, 1 course	12
La Trobe University (Biology)	1 academic, 2 courses	270
La Trobe University (Chemistry)	1 academic, 1 course	409
La Trobe University (Physics)	1 academic, 1 course	31
University of Adelaide (Biology)	1 academic, 1 course	43
University of Queensland (Chemistry)	1 academic, 1 course	178
University of Queensland (Chemistry)	1 academic, 1 course	25
University of Sydney (Physics)	2 academics, 3 courses	458

Total surveys distributed: 1823

Semester 1, 2010

Institution	Number of academics	Number of surveys distributed
Curtin University (Chemistry)	3 academics, 4 courses	386
Curtin University (Physics)	3 academics, 4 courses	???
La Trobe University (Physics)	2 academics, 1 course	270
Monash University (Chemistry)	1 academic, 1 course	80
Swinburne University (Chemistry)	1 academic, 7 courses	337
University of Adelaide (Chemistry)	1 academic, 2 courses	212
University of Adelaide (Physics)	1 academic, 2 courses	300
University of Newcastle (Chemistry)	1 academic, 1 course	???
University of Sydney (Biochemistry)	1 academic, 2 courses	367
University of Sydney (Chemistry)	1 academic, 7 courses	1036
University of Wollongong (Biology)	1 academic, 1 course	245

Total surveys distributed: 3233

Semester 2, 2010

Institution	Number of academics	Number of surveys distributed
Curtin University (Chemistry)	3 academic, 5 courses	309
Curtin University (Physics)	3 academic, 4 courses	???
Griffith University (Biology)	1 academic, 1 course	43
University of Adelaide (Chemistry)	1 academic, 2 courses	419
University of Queensland (Physics)	1 academic, 1 course	400
University of Sydney (Biochemistry)	1 academic, 2 courses	286
University of Sydney (Chemistry)	1 academic, 6 courses	664
University of Sydney (Physics)	2 academics, 3 courses	414
University of Wollongong (Biology)	1 academic, 1 course	475

Total surveys distributed: 3010

Grand total: 14974 surveys with some (???) still to be determined.

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