Improving Student Engagement in the Laboratory: An Initiative across all Australian Universities

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Australian Chemistry Context

• ~20,000 students undertake chemistry units each year, spread over 35 universities.
• $\frac{1}{3} - \frac{1}{2}$ of time in laboratory-based activities
• Potential benefits from lab work
  – Develop technical skills
  – Make theory more concrete
  – Engage students in the practices of science
• Challenge: Providing a lab program that
  – Demonstrably lives up to its potential
  – Within existing constraints
APCELL → ACELL → ASELL

• APCELL began 2000.
  – Physical chemistry focus.

• Evolved to ACELL in 2004.
  – All-of-chemistry expansion.

• ASELL (S = Science) Sep 2009.
  – Biology, Chemistry, Physics.
  – ACDS collaboration.
    (Australian Council of Deans of Science)
ASELL

• Four principal aims
  – Database of **educationally** and **scientifically** sound experiments, that have been **tested** by both academic staff and students.
  – Provide for **professional development** of science academic staff.
  – Facilitate the development of a science education **community of practice**.
  – Researching **learning** in the laboratory environment.
ASELL Aim 1

Database of **educationally** and **scientifically** sound experiments, that have been tested by both academic staff and students.

Scientifically sound =
- accurate science
- works reliably
- safe
- transferrable to another location
ASELL Workshops:

- Set up for 3rd party testing of experiments (i.e. away from the experiment’s “home” lab);
- Experiments tested by staff and students (typically ~50:50);
- Tested under as realistic conditions as possible (3 hour lab, 8 “students” per experiment);
- Extensive feedback given to submitters – both formal and informal.
Workshops:

- July, 2000 (Canberra)
- Feb, 2001 (Sydney)*
- Feb, 2002 (Christchurch)
- Nov, 2002 (Melbourne)*
- Feb, 2004 (Hobart)*
- July, 2005 (Sydney)
- Feb, 2006 (Sydney)*
- Jan, 2007 (Adelaide)*
- July, 2007 (Auckland)
- Nov, 2007 (Sydney, physics)*
- Apr, 2008 (Adelaide, biology)*
- July, 2009 (Sydney)*
- April, 2010 (Adelaide, biol, chem, phys)*

* experimental workshops
Participating in this ACELL-style workshop has reminded me of what it is like to be a student.

Pairs of staff

Pairs of staff+student

Pairs of staff+student, staff+staff and student+student
ASELL Aim 2

Provide for professional development of science academic staff.

• Recognition of the potential in this area evolved over time

• Facilitated through
  – Workshops
  – the Educational Template
  – ASELL Student Learning Experience Survey
  – New instruments being developed.
“Participating in the ASELL workshop has increased my understanding of educational issues”
Methods – Educational Template

• Section 1 – Summary of the Experiment
• Section 2 – Educational Analysis
  – Learning outcomes in areas
    • Theoretical and Conceptual Knowledge
    • Scientific and Practical Skills
    • Thinking Skills and Generic Attributes
• Section 3 – Student Learning Experience
• Section 4 – Documentation
Section 2 – Educational Analysis

For each learning outcome:

– What should students learn?
– How will students learn it?
– How will staff and students know that students have achieved the learning outcome?
Providing Lab Development Tools

I would use the ACELL educational template when designing a new laboratory exercise

- Staff (n = 26)

ASELL Aim 3

Facilitate the development of a science education community of practice.
Shared experience...

- Networking through workshops;
- Communication via website and email;
- ACELL presence at all Australian Chem. Ed. Conferences since 2002;
- ACELL sponsorship of attendance at initial workshops (this is important to establish community).
Mentoring

• ASELL provides educationally validated survey instruments, plus instructions on their use and interpretation;

• assistance in proper ethical treatment of surveys and data, inc. ethics applications;

• assistance in preparing an educational research manuscript, inc. pointers to key literature, educational concepts, etc.
The ACELL Website

- Experiments and their documentation
- Publications, including published papers
  - Published experiments from A(P)CELL
- Information on ACELL events
- Education resources for ongoing professional development
  - Process information – content analysis
  - Theory information – constructivism

www.acell.org
www.asell.org launched soon
Hydroboration-Oxidation of an Olefin: Octyl Alcohol

Introduction

The hydroboration-oxidation of 1-octene to prepare the anti-Markovnikov addition product, 1-octanol, is performed in this experiment using BH₃-THF for the hydroboration and basic H₂O₂ for the oxidation.

The ratio of anti-Markovnikov product, 1-octanol, to the Markovnikov addition product, 2-octanol, is measured by gas chromatography. Because the addition reaction known as “hydroboration” is general for all classes of acyclic and cyclic alkenes as well as alkenes, it is a powerful synthetic tool.

It provides an introduction to the handling of air-sensitive reagents and also gives students experience running a gas chromatograph (GC). The reaction is done on microscale (ca. 1.3 mmol) to give students experience carrying out synthetic transformations on small quantities of material. To make efficient use of time, students can be trained to run the GC standards of 1-octanol and 2-octanol after the hydroboration has been initiated.

Level of Experiment
Documents in the Demonstrator Notes, Technical Notes, Hazard and Risk Assessment, and Feedback categories are only available to users with Academic accounts. Users with Ordinary accounts can contact us to request an upgrade if they hold an academic appointment, or have another legitimate reason for requesting an upgrade to an Academic account.

### Student Notes

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### Demonstrator Notes

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### Additional Notes / Documents

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<tr>
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| Two representations of the structure of tris(2-(diphenylphosphino)ethyl)phosphine, tetraphos-2, P(CH₂CH₂P₂P₂)₃.
| Tetraphos-2 (GIF Image) | GIF Image      | 8kb   |
| Full structure of tris(2-(diphenylphosphino)ethyl)phosphine, tetraphos-2, P(CH₂CH₂P₂P₂)₃.

### Educational Template

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ASELL Aim 4

Researching **learning** in the laboratory environment.

• Work of the Director team

• Providing an evidence base for strategic planning (e.g., ACDS).

(Australian Council of Deans of Science)
1. Survey of student learning experience in laboratory (ASLE);
   • focuses on a single experiment;
   • survey students as they leave the laboratory.

2. Student evaluation of whole laboratory program (ALPE);
   • surveyed at end of semester, after all assessment
   • brand new, only baseline data collected so far
   • Deans main interest!

3. Staff survey, predicting which factors influence student learning experience in labs
   • probes prior concepts of staff
The ASLE Instrument

• Designed to test the educational issues expounded in the Educational Template
  – Should serve to improve the student experience via aspects of education theory that the teacher has been exposed to and trained in.

• Questions reflect current educational theories
  – Interest, content knowledge, generic skills, discipline skills.
  – Disguised in “everyday” language.

• 3 different metrics:
  – 14 x Likert questions.
  – 5 x open ended questions.
  – Recorded interviews.

• Validation
  – ACELL workshops, with iterations.
  – On-going process.
Q14: Overall, as a learning experience, I would rate this experiment as:

A: Outstanding
B: 
C: 
D: 
E: Worthless

A: +4  
B: +3  
C: +2  
D: +1  
E: 0
Wide range of learning experiences

Q14: Overall, as a learning experience, I would rate this experiment as

score = +1.61

Students, (n = 23)

score = +3.14

Students, (n = 28)
14 Likert items:

Q1: This experiment has helped me to develop my data interpretation skills.
Q2: This experiment has helped me to develop my laboratory skills.
Q3: I found this to be an interesting experiment.
Q4: It was clear to me how this laboratory exercise would be assessed.
Q5: It was clear to me what I was expected to learn from completing this experiment.
Q6: Completing this experiment has increased my understanding of (discipline).
Q7: Sufficient background information, of an appropriate standard, is provided in the introduction.
Q8: The demonstrators offered effective support and guidance.
Q9: The experimental procedure was clearly explained in the lab manual or notes.
Q10: I can see the relevance of this experiment to my (discipline) studies.
Q11: Working in a team to complete this experiment was beneficial.
Q12: The experiment provided me with the opportunity to take responsibility for my own learning.
Q13: I found that the time available to complete this experiment was:
Q14: Overall, as a learning experience, I would rate this experiment as:
What would you predict?

Q1: Data interpretation skills
Q2: Developing laboratory skills
Q3: Interest
Q4: Clear assessment
Q5: Clear learning objectives
Q6: Increased (discipline) understanding
Q7: Sufficient/appropriate background
Q8: Effective demonstrators
Q9: Good prac notes
Q10: Relevance to (discipline) studies
Q11: Developing teamwork
Q12: Responsibility for own learning

Q14: Overall, as a learning experience, I would rate this experiment as:
Be careful!

The student survey has 12 INDEPENDENT questions:

for example: Item 42 might have been
“I was made to work hard in this practical”

Few students would respond that they had an excellent learning experience BECAUSE they worked hard. But we might find that in all labs that students say they had a good learning experience that they did, in fact, work hard.
Which responses correlate best (& worst)?

Q1: Data interpretation skills
Q2: Developing laboratory skills
Q3: Interest
Q4: Clear assessment
Q5: Clear learning objectives
Q6: Increased (discipline) understanding
Q7: Sufficient/appropriate background
Q8: Effective demonstrators
Q9: Good prac notes
Q10: Relevance to (discipline) studies
Q11: Developing teamwork
Q12: Responsibility for own learning
Return to staff predictions…

- **128 academic staff**
  - 38 chemistry
  - 59 physics
  - 31 biology

- **Surveyed at**
  - Sydney W/S (Chemistry)
  - Uniserve conference (Physics & Biology)
  - Adelaide W/S (Chemistry, Physics, Biology)
  - US large state university (Physics)
  - US private university (Chemistry)
Overall responses, $n = 128$

**Rank**

1. Q3: Interest

2. Q10: Relevance to (discipline) studies

3. Q8: Effective demonstrators

4. Q6: Increased (discipline) understanding
Differences between disciplines

Discipline rank vs. All staff rank

Top 4 correlators:
- Interest
- Relevance
- Demonstrators
- Understanding

Bottom 4 correlators:
- Teamwork
- Responsibility
- Data analysis
- Background
US vs Australia comparison

Teamwork

R² = 0.65
P < 0.001
What do students in the labs say?

The dataset:

- 30 experiments (28 chemistry, 2 physics)
- surveyed in 8 different universities (same instrument)
- across all of discipline and years of chemistry
- paper + web surveys
- combination of ASELL and “other” experiments
- >1500 responses overall (min = 13, max = 143, avg = 47)
Compare staff with students

![Graph showing comparison between staff and student ranks for Teamwork and Interest](image)

- **Staff rank** (n=130) vs **Student rank** (n=1500)

- **Teamwork**
- **Interest**
Compare staff with students

- All staff ($n=128$)
- Chemistry ($n=38$)
Compare staff with students

What happened everywhere else?

Q1: Data interpretation

All picked highest correlation = “Interest”

Q8: Effective demonstrators

All picked lowest correlation = “Teamwork”
Explore ASLE results further…

- “Interest” was well-picked

**Scale:**
2: Strongly Agree
1: Agree
0: Neither Agree nor Disagree
-1: Disagree
-2: Strongly disagree

"I found this to be an interesting experiment"

\[ Y = -2.24 + 1.25 X \]

\[ R^2 = 0.75 \]

\[ P < 0.001 \]
Explore ASLE results further…

• “Teamwork” was well-picked

From written feedback:
Good teamwork can enhance a good prac, or just allow a student to get through a poor prac.

Y = 0.60 + 0.25 X
R² = 0.19
P = 0.31

Teamwork (Q11) score
Overall score

"Working in a team to complete this [experiment] was beneficial"
Explore ASLE results further...

• “Data analysis” was poorly picked

From written feedback:
Mindless collecting of data, or just making observations is not engaging. The process of “working up the data”, or “getting inside the data” to achieve understanding was very highly valued.
Explore ASLE results further…

- “Demonstrators” was poorly picked

"The demonstrators offered effective supervision and guidance"

From written feedback:
Poor demonstrators can destroy a good practical, but great demonstrators cannot rescue a poor prac. (Students are very capable of assessing demonstrators completely separately from the prac experience.)
Overall correlations

- **Strong correlation** ($R^2 \geq 0.60$)
  - Interest, understanding of chemistry,
  - data interpretation, responsibility for own learning

- **Medium correlation**
  - Learning objectives, procedure & instructions, relevance to my studies

- **Weak correlation** ($R^2 < 0.4$)
  - Demonstrators, lab skills,
  - team work, background info, assessment
Current activity

• Baseline lab program evaluation
  – 49 Lab programs have had baseline surveys conducted
    • involving >600 practicals
    • all levels of chemistry, physics, biology
    • science majors and service courses
• Use ASLE to identify weak labs
  – being done in 14 programs
• Re-evaluate whole lab program
  – planned for the current semester
• Explore whether course evaluation questionnaires improve (this is what the Dean care about!)
Where to from here?

International activity

- workshop in Ireland, June, 2010
- workshop in Philippines, August, 2010
  - ASELL surveys being run in 49 universities
- NSF grant under evaluation (chemistry only)
  (PI = Prof MaryKay Orgill, UNLV)
ASELL Directors

- Mark Buntine (Curtin)
- Scott Kable (Sydney)
- Karen Burke da Silva (Flinders) - Biology
- Kieran Lim (Deakin) - Chemistry
- Manju Sharma (Sydney) - Physics
- Simon Pyke (Adelaide) - ACDS
- Simon Barrie (Sydney)

- Alex Yeung – Project Manager Extraordinaire!

- International Advisory Panel members:
  - Prof MaryKay Orgill (UNLV)
  - Prof George Bodner (Purdue)
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AUSTRALIAN LEARNING & TEACHING COUNCIL
Promoting excellence in higher education
Why are these factors strongly and weakly correlated?

- ‘motivation’ vs ‘maintenance’ factors?
Motivation vs Maintenance…

Or:
Why don’t “demonstrators” and “clear assessment” correlate well with overall evaluation of lab?

• An Australian Chemistry Department has used the ASLE instrument to evaluate every freshman undergraduate experiment they offer in one semester.

• What has been found?
"The demonstrators offered effective supervision and guidance"

\[
Y = -0.13 + 0.55 X \\
R^2 = 0.39
\]

"It was clear to me how this [laboratory exercise] would be assessed."

\[
Y = -0.77 + 0.59 X \\
R^2 = 0.41
\]
Lab skills & Teamwork…

"This experiment has helped me to develop my laboratory skills"

Y = 0.40 - 0.04 X
R² = 0.19

"Working in a team to complete this [experiment] was beneficial"

Y = 0.14 + 0.41 X
R² = 0.11
"I found this to be an interesting experiment"

\[ Y = -2.17 + 1.21 \times \]

\[ R^2 = 0.75 \]

"Completing this experiment has increased my understanding of chemistry"

\[ Y = -1.12 + 0.80 \times \]

\[ R^2 = 0.75 \]
"This [experiment] helped me to develop my data interpretation skills."

\[ Y = -0.87 + 0.66 \times X \]
\[ R^2 = 0.70 \]

"The [experiment] provided me with the opportunity to take responsibility for my own learning."

\[ Y = -0.35 + 0.23 \times X \]
\[ R^2 = 0.64 \]
Overall correlations

- Strong correlation ($R^2 \geq 0.60$)
  - Interest, understanding of chemistry, data interpretation, responsibility for own learning

Current ASELL acceptance criteria:

- score $> +0.5$ on 3 out of 4 of the above
- AND score $> 2.2$ on “overall” rating