Making Laboratory Exercises Good Learning Experiences:

The ACELL Project

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(Directors, ACELL)

ACELL
Advancing Chemistry by Enhancing Learning in the Laboratory

Context

Some "facts":

- 35 Australian universities teach chemistry - at least to First Year.
- ~20,000 students per year take these courses.
- Laboratory training is an ESSENTIAL component in chemical education.
  - RACI accreditation = 350 hours / B.Sc.
  - 2006 "Future of Chemistry" Report: 48% of student time in lab.

Laboratories:

Chemistry is particularly vulnerable to student discontent in the laboratory

- Arcane concepts;
- Perceived lack of relevance;
- Reliance on instruments as black boxes;
- Following recipes;
- Boring and/or repetitive.

History of ACELL

- Project began 1999 as APCELL
  - Physical Chemistry focus
- 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
  - Doing so within existing constraints

APCELL

- Bring departments together.
- Build on established effective experiments.
- Provide resources needed to implement new experiments easily:
  - Technical Notes.
  - Demonstrator Notes.
  - Student Notes.
  - Results Proforma.
  - Hazard Assessment.

Outcomes of APCELL

- Database of educationally validated experiments
- The Educational Template
- Workshops at Australian Phys. Chem. and Chem. Ed. conferences
- Collaboration with the *Australian Journal of Education in Chemistry*
- Uptake of experiments and methods by Chemistry departments
- Network of academics and students
- Communication

Refereeing and Publications

All of Chemistry – ACELL

- Four principal aims
  - Database of educationally and chemically sound experiments, that have been tested by both academic staff and students.
  - Provide for professional development of chemistry academic staff.
  - Facilitate the development of a chemistry education community of practice.
  - Researching learning in the laboratory environment.

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Discussion Time…

Why aren't all chemistry labs great learning experiences already?

Discussion Time…

If you were planning a new experiment from scratch, what elements would you build into it?

Discuss…

- In small groups, an example, from your days as a student, of a chemistry lab that was a **good** student learning experience.
- What was it that made the good labs a good student learning experience?

Discuss…

- In small groups, an example, from your days as a student, of a chemistry lab that was a **bad** student learning experience.
- What was it that made the bad labs a bad student learning experience?

The Path to the Present…

- It wasn't considered as much in the "old days"
  - …and a lot more is known about the learning process now
- Now… is there enough time for thinking about teaching?
- Academic staff don't get enough time to think about:
  - Content goals – what we want students to learn
  - Process – activities we design to assist student learning
  - Outcomes – evidence required to 'measure' student learning

A Question…

What do you think are the criteria for a high quality undergraduate chemistry laboratory?

Another Question…

What do you think students say makes a good chemistry lab?

What Chemistry Students Think Makes a Good Lab…

Make it

- relevant to why I'm here
- a good use of my time
- applicable to my world
- clear why I'm doing the lab
- clear what I am supposed to take away
- challenging, but do-able

What Chemistry Students Think Makes a Good Lab…

Let me

- do something of which I can be proud
- have fun – laboratory work shouldn't be a chore
- engage my mind and not just my hands
- have the help I need, but don't take over – support my autonomy and allow me choice
- see that you value my efforts and achievement

Chemistry Student Feedback…

- "If we are simply following a recipe without thinking about what we are doing and without any idea of why we are doing it – sure we get through the lab, but what have we learnt … nothing much."
- "What is learnt along the way is what makes the journey worthwhile, how we get there counts – it's why I'm here."

What Does the Educational Research Say…

- Similar things, but more cautiously…
  - By following a recipe students "*are not 'doing an experiment', but 'carrying out an exercise'*"
  - making limited intellectual demands on students, who "*often seem to go through the motions…with their minds in neutral*".
  - Bennett and O'Neale (1998, p. 59)
- Insufficient evidence of benefits from lab work …Hofstein and Lunetta (1982, 2004)

Guidance on Other Considerations

- Student-Centred / Constructivist Perspectives
- Not Discovery…
  - Mayer, 2004
  - Kirschner, Sweller, & Clark, 2006 (+ responses)
- Design Issues around Cognitive Load
  - Sweller, 1994
  - Johnstone and Al-Shuaili, 2001

Back to ACELL Aims…

1. Database of educationally and chemically sound experiments, that have been tested by both academic staff and students.
2. Provide for professional development of chemistry academic staff.
3. Facilitate the development of a chemistry education community of practice.
4. Researching learning in the laboratory environment.

ACELL Aim 1

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

Chemically sound =
chemically accurate
+ works reliably
+ safe
+ transferrable to another location

ACELL 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)**

** experimental workshops*

February 2006 ACELL Workshop

- 33 academic staff
- 31 undergraduate students
- 27 universities from across Australia and New Zealand
- 33 experiments

- 3 very full days

Workshop Program

	8:30 am to 9:00 am	9:00 am to 10:00 am	10:00 am to 1:00 pm	1:00 pm to 2:00 pm	2:00 pm to 5:00 pm	5:00 pm to 5:30 pm	5:30 pm to 6:00 pm	6:00 pm to 7:00 pm	7:00 pm to ???
	Lecture Theatre 4		Level 3 and Level 5 Laboratories	Lecture Theatre 2 Foyer and Chemistry School Courtyard	Level 3 and Level 5 Laboratories			"The Pub" Royal Hotel	
Monday 13 Feb	Registration	Welcome and Introduction	Experiments	Lunch	Experiments	Clean Up and Set Up		Review of Experiments	Dinner at Royal Hotel
Tuesday 14 Feb	Forum on Student Refereeing	Panel Discussion	Experiments	Lunch	Experiments	Clean Up and Set Up		Review of Experiments	Dinner at Royal Hotel
Wednesday 15 Feb		Panel Discussion	Experiments	Lunch	Experiments, plus Clean Up	Final Discussion, LT4		Review of Experiments	Workshop Dinner at Buon Gusto

Physics Workshop photos:

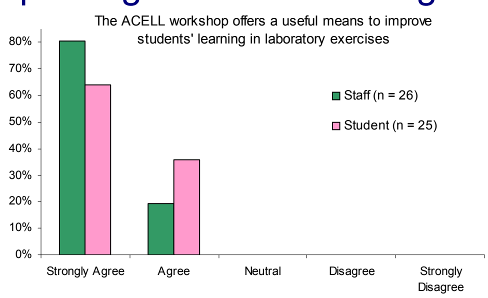
Pairs of staff

Pairs of students

Physics Workshop photos:

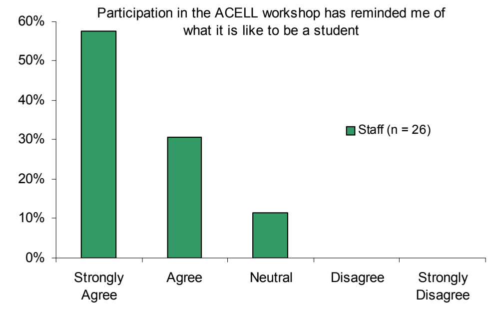
Pairs of staff + student

Improving Student Learning



Buntine *et al.* (2007). *CERP*, **8,** 232-54.

Being a Student



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Delegate Feedback

- Staff: "It made me sit down and think carefully about what I wanted my students to get out of my experiment, and how I could judge if they had been successful"
- Student: "I learnt that also there are teachers / lecturers that actually do care about their students and want to improve their learning experience"

Educationally tested:

Educationally tested =
set of learning objectives
+ recognised processes to facilitate learning objectives
+ indicators so staff and students can each judge achievements

- staff are not very good at writing down educational objectives and validation of objectives (assessment, etc)

ACELL Aim 2

Provide for professional development of chemistry academic staff.

- Recognition of the potential in this area evolved over time
- Facilitated through the Educational Template developed for APCELL
- ACELL student learning experience survey

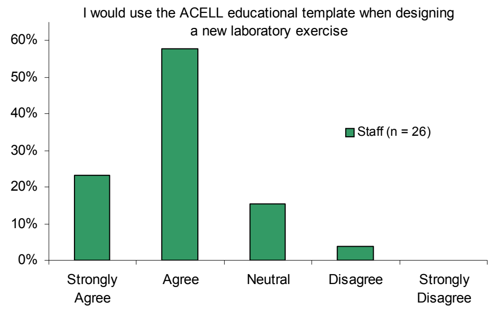
Methods – Educational Template

- 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



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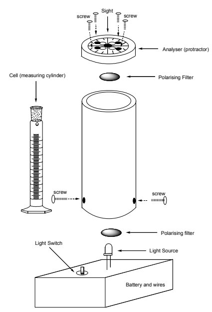
The "Student Learning Experience" Instrument

- 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.

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 chemistry.
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 chemistry 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:

Demystifying the polarimeter (A new ACELL experiment)

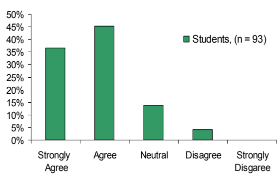


Value for individual experiments…

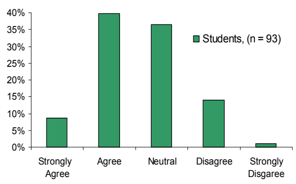
Highlighting strengths and weaknesses:

Expt: "Investigation of rotation of plane polarised light using a home-made polarimeter"

Q10: "I can see the relevance of this experiment to my chemistry studies"

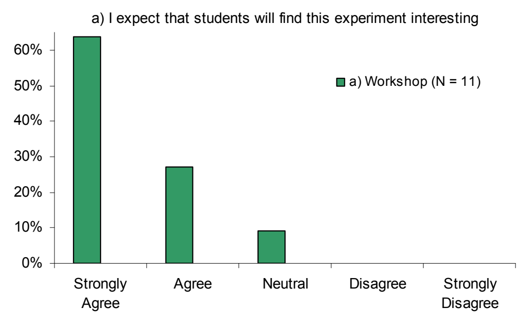


Q3: "I found this to be an interesting experiment"

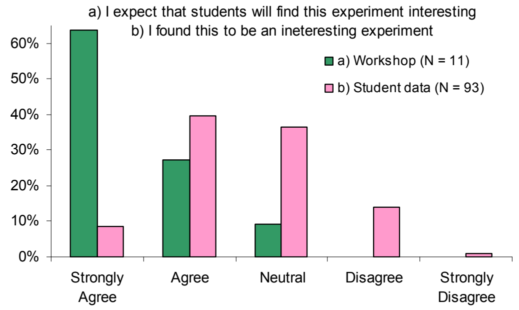


Crisp (2008), Unpublished Data

Unusual workshop / ASLE data:



Unusual workshop / ASLE data:



Literature on Interest

- Ideas of ‘caught’ and ‘held’ attention are old
- Situational and Individual Interest
  - Mitchell, 1991
  - Krapp, Renninger, & Hidi, 1992
- Four-Phase Model of Interest
  - Hidi and Reninger (2006)

ACELL Aim 3

Facilitate the development of a chemistry 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).

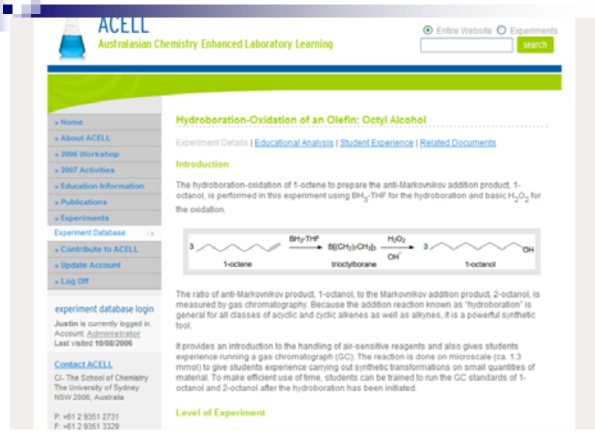
Mentoring

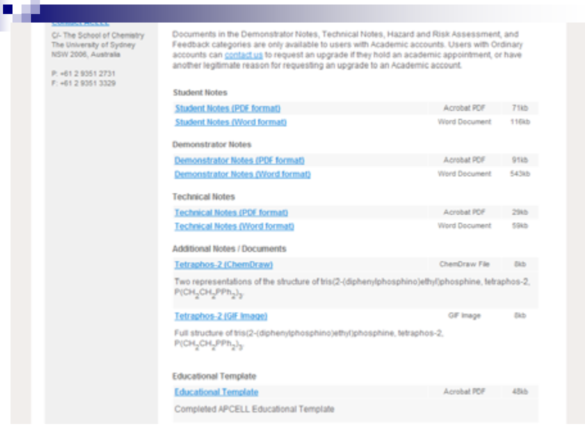
- ACELL provides educationally validated survey instruments;
- assistance in proper ethical treatment of surveys and data;
- assistance in preparing an educational research manuscript, inc. pointers to key literature, educational concepts, etc

The ACELL Website

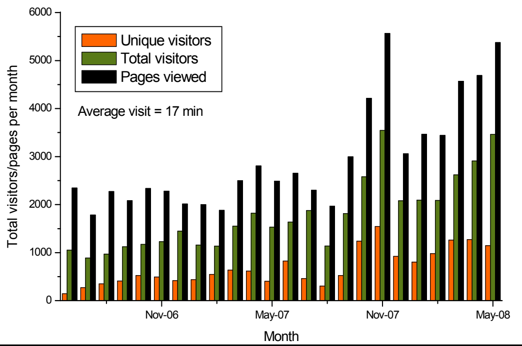
- Experiments and their documentation
- Publications, including published papers
  - 13 published experiments from APCELL
  - 2 published papers from ACELL
- Information on ACELL events
- Education resources for ongoing professional development
  - Process information – content analysis
  - Theory information – constructivism

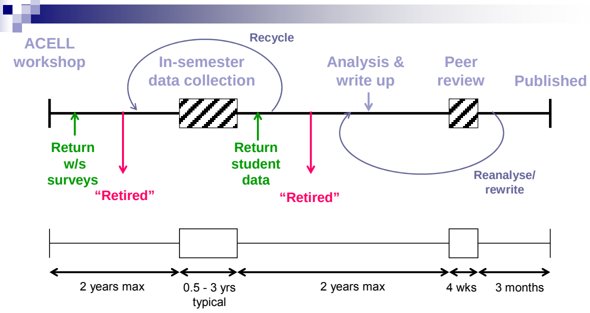
- http://acell.chem.usyd.edu.au





Web site activity…





APCELL – around 35 experiments workshopped
15 published in the *Australian Journal of Education in Chemistry*

ACELL – 37 experiments workshopped to date
1 published in *Chemistry Education Research and Practice*
2 retired, 34 remain at various stages of the above process

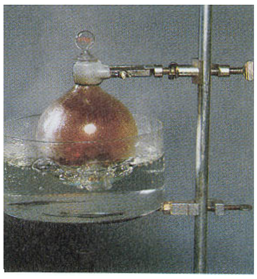
Example: Thermodynamics Think-In

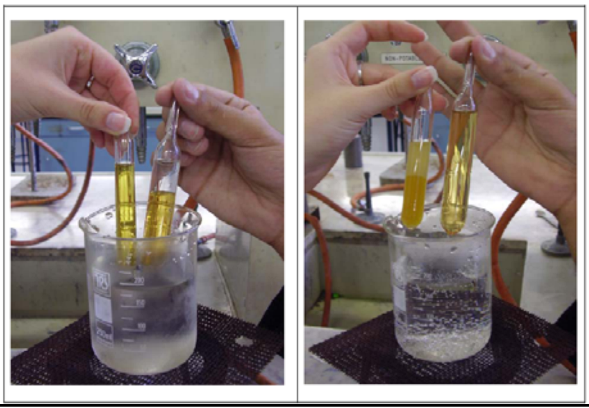
- Two separate sequences of 5 experiments
  - Increasing challenge
  - Qualitative – explanation not calculation
- Must explain each to progress
- Includes discrepant event (POE model)
  - Heating a rubber band
  - Separate by heating

Read & Kable (2007)

Time for experiments!

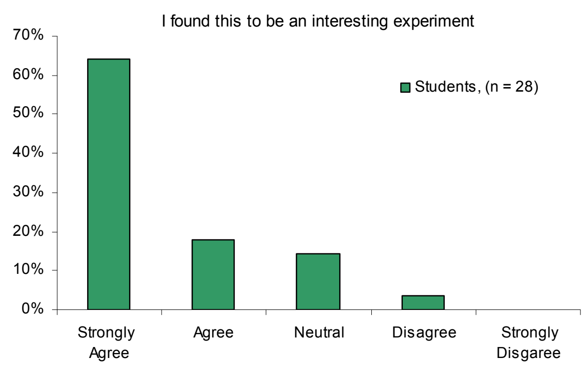
NO$_2$ (effect of temperature)

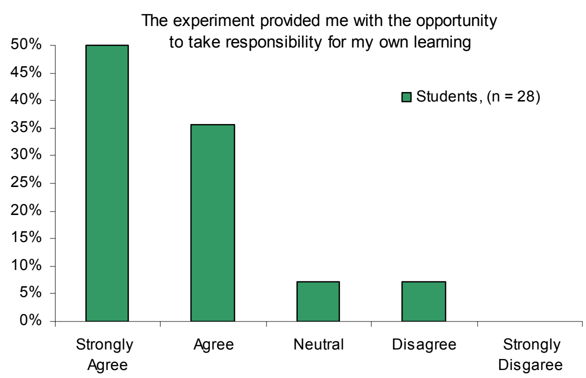


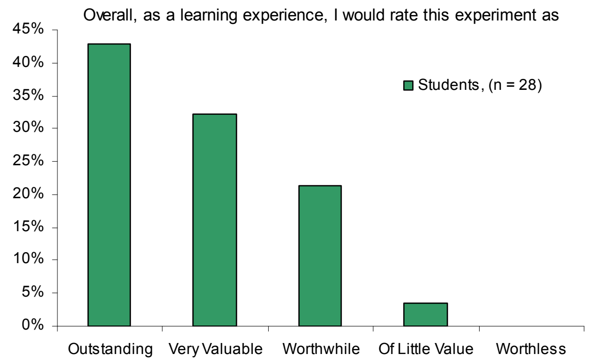


Thermal properties of rubber

“Drinking duck”







Design Features

- Truly cooperative learning
- Challenge increases
- Context of real-world objects
- Discrepant Events – reconcile predictions
- Guided but with genuine self-direction
- Interesting according to students
- *Students* introduced choice

ACELL Aim 4

Researching learning in the laboratory environment.

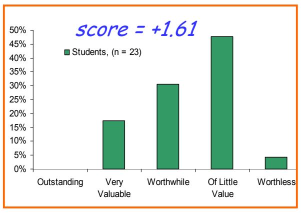
- Work of the Director team

Students' perceptions of learning experience:

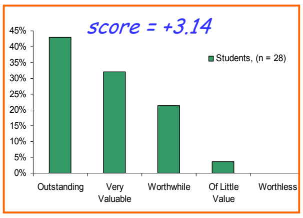
Q14: Overall, as a learning experience, I would rate this experiment as:

A: Outstanding
B: Very valuable
C: Worthwhile
D: Of little value
E: Worthless

Wide range of learning experiences



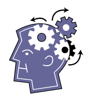
Q14: Overall, as a learning experience, I would rate this experiment as



Score = average

A:	+4
B:	+3
C:	+2
D:	+1
E:	0

What are the main factors, from the students' perspective, that correlate with this overall experience?



Q1: Developing data interpretation skills
Q2: Developing laboratory skills
Q3: Interest
Q4: Clear assessment
Q5: Clear learning objectives
Q6: Increased chemistry understanding
Q7: Sufficient/appropriate background
Q8: Effective demonstrators
Q9: Good prac notes
Q10: Relevance to chemistry studies
Q11: Developing teamwork
Q12: Responsibility for own learning
Q13: Sufficient time to complete

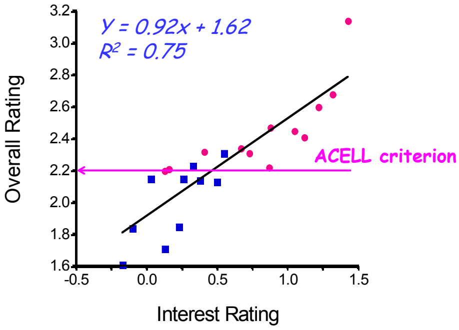
The dataset

- 22 experiments
- surveyed in 8 different universities (same instrument)
- across all of chemistry (sub-discipline and year level)
- paper + web surveys
- combination of ACELL and "other" experiments
- >1300 responses overall (min = 13, max = 143, av = 47)

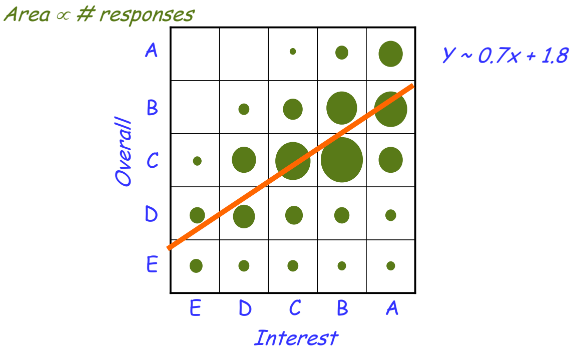
Strongly correlated

Interest:

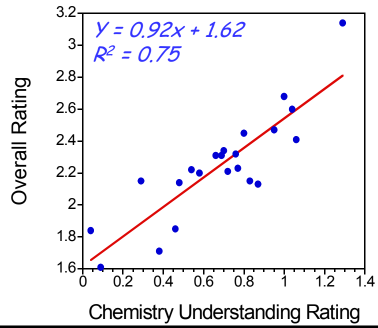
SA:	+2
A:	+1
N:	0
D:	-1
SD:	-2



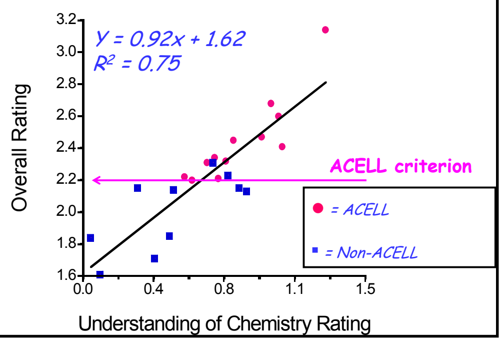
Higher order correlation…



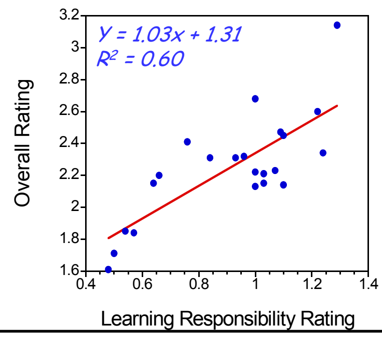
Strongly correlated



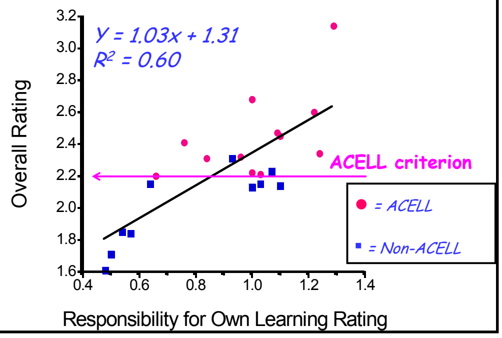
Strongly correlated



Strongly correlated



Strongly correlated



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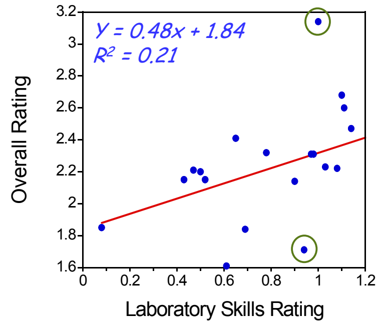

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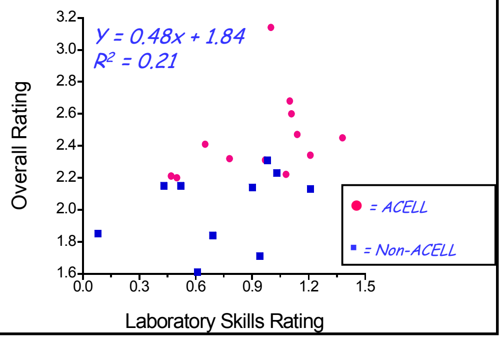

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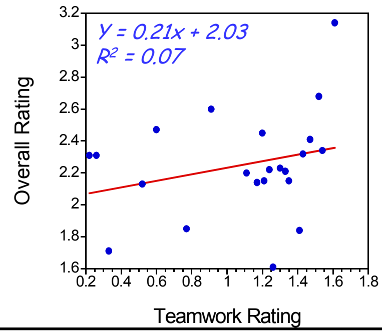

Overall correlations

- 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

Influences of Students' Perception of the Learning Experience

Survey Item	R^2 v Overall	Slope	ACELL	Non-ACELL
Interest	0.75***	0.61 ± 0.16	+0.832	+0.212
Understanding of Chemistry	0.75***	0.93 ± 0.25	+0.843	+0.489
Data Interpretation Skills	0.67***	1.04 ± 0.34	+0.700	+0.500
Responsibility for Own Learning	0.60***	1.03 ± 0.40	+1.02	+0.786
Laboratory Skills	0.21*	0.48 ± 0.43	+0.949	+0.738
Overall	1		+2.45	+2.01

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Where to from here…?

- A model for other domains:
  - Evolution to ASELL (S=science)?
    - chemistry.asell
    - biology.asell (first biology w/s held in Adelaide, 4/08)
    - physics.asell (first physics w/s held at UTS, 12/07)
    - etc.
- A model for other countries?

ACELL (UK or Europe?)

- Would the ACELL approach work in the more diverse university sector of UK/Europe?
- Would there be any interest in running ACELL workshops and sharing labs?

Acknowledgements

"The Team"

Sydney:
- *Simon Barrie*
- *Adrian George*
- *Scott Kable*

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- *Mark Buntine*
- *Geoff Crisp*
- *Justin Read*

Macquarie:
- *Ian Jamie*

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- *Bob Bucat*

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