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The ACELL project: Student participation, professional development, and improving laboratory learning

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Introduction

Chemistry is an 'enabling science' as its core concepts are essential for almost every area of science (White, O'Connor, Mousley, Cole and MacGillivray 2003) and it is studied both as a discipline in its own right and as a central component of other degree programs. Across 35 Australian universities, more than 20 000 students are taught chemistry each year (Barrie, Buntine, Jamie and Kable 2001a). Chemistry is also a highly conceptual discipline, requiring an ability to deal with phenomena at both a macroscopic and microscopic level, and to connect with symbolic representations used at each of these levels. Students may experience difficulties with their learning if this symbolic language is taken for granted, and there is a risk that connections between the material world and theoretical constructs may be misunderstood (Marais and Jordaan 2000; Kozma, Chin, Russell and Marx 2000; Bucat 2004). The laboratory environment is a bridge between theory and praxis, it offers unique opportunities to assist students as they attempt to construct an understanding of these connections.

Much has been written on the learning goals that can be achieved through laboratory work, in terms of both knowledge and skill development (Hegarty-Hazel 1990; Moore, 2006). It is well established that effective experiments do not utilise a 'follow the recipe' structure (Domin 1999), as students can 'go through the motions ... with their minds in neutral' (Bennett and O'Neale 1998, p. 59); equally, pure discovery approaches are ineffective (Mayer 2004) as they lack necessary structure. In short, experiments need to be designed to support student autonomy (Skinner and Belmont, 1993) whilst requiring cognitive engagement. Ways in which this may be achieved include designing open-ended experiments (Psillos and Niedderer 2002), incorporating inquiry-based learning activities (Green, Elliot and Cummins 2004), or having students work collaboratively to solve a problem (Shibley and Zimmaro 2002) – this improves motivation (Paris and Turner, 1994), and also allows students to scaffold each other's learning (Coe, McDougall and McKeown 1999).

According to the recent *Future of Chemistry* report (Royal Australian Chemical Institute 2005), 48% of student time is spent in laboratory work, and so it is very important that the opportunities afforded by this substantial learning environment are realised. The value of laboratory activities beyond simply developing technical skills (such as handling glassware) has been questioned, most recently by Hawkes (2004), who argues that the technical skills developed do not justify the expense and time associated with laboratory activities,

especially for non-science majors. This position has been criticised (Morton, Sacks and Stephens 2005; Baker 2005), but it does illustrate a challenge facing chemistry educators – to provide compelling evidence of what laboratory classes achieve.

The Australasian Chemistry Enhanced Laboratory Learning (ACELL) project

The Australian Physical Chemistry Enhanced Laboratory Learning (APCELL) project (Barrie, Buntine, Jamie and Kable 2001a, 2001b, 2001c), and its all-of-chemistry successor, ACELL (Read, 2006a) are examples of contemporary efforts to meet the challenge of engaging students in laboratory activities which are both chemically and educationally sound. The project is collaborative; it overcomes many of the significant constraints imposed by the unavailability of time from individual teachers, by drawing on the resources and expertise of multiple institutions as well as chemical and pedagogical expertise. The project continues to produce a range of tangible outcomes, including chemistry education research publications, a database of freely available tested experiments, and pedagogical design tools (all available from <http://acell.chem.usyd.edu.au/>). Objective evidence is required to support the putative notion that the A(P)CELL concept is of benefit to educators as they design and evaluate laboratory programs; collection and evaluation of such empirical data is essential if views such as those of Hawkes (2004) are to be effectively challenged. In this paper we report on the views of staff and student delegates to the February 2006 ACELL Educational Workshop.

The ACELL project has three principal aims: (i) to make available, via a database, materials relating to undergraduate chemistry experiments which are educationally sound and have been evaluated by both students and academic staff. These materials consist of everything needed to introduce the experiment into another institution, as well as evaluation data relating to both the chemical and the educational aspects of the experiment; (ii) to provide for the professional development of chemistry academic staff by expanding the understanding of issues surrounding student learning in the laboratory; and, (iii) to facilitate the development of a community of practice in chemistry education within the broader academic community of the Australasian region.

A significant problem arising from the collaborative nature of ACELL is that most chemists at the teaching/learning interface are discipline experts, but are not well read in education research. Such research has its own language and methodologies that are not always transparent to those outside the field, and is published in journals not usually accessed by chemists. ACELL therefore initially seeks to engage academics in reflecting on their own curriculum decisions about teaching and design of laboratory practice (Brew and Barrie 1999), whilst simultaneously providing an accessible entry point or bridge into educational concepts (Read 2006b). This is achieved in the first instance by engaging participating academics at the level of their teaching and learning principles, rather than at the level of teaching behaviours. Processes that encourage academics to adopt a learner-focused design perspective are used; these start with the participants' own conceptions of teaching, even if these are teacher-focused, then reflect on, and challenge these ideas in developing the parameters for the design of laboratory programs. An intensive workshop-style format, preceded by academics submitting what they consider to be exemplar experiments, has been used to initiate this engagement and reflective process. The first APCELL workshop was held in February 2000, whilst the first ACELL workshop was held in February 2006; both events were held at the University of Sydney.

The workshop format involves an early morning discussion session focussing on a particular educational theme, with mid-morning and early-afternoon laboratory sessions. In these laboratory sessions, most delegates take on the student role in testing experiments, with each staff delegate spending one day demonstrating the experiment they have submitted. Each day concludes with a focussed debrief and discussion session where delegates critically evaluate the experiments they undertook that day. Delegates are assigned to work

with different people in each laboratory session, facilitating the mixing of delegates from a range of sub-discipline areas, geographic locales, and / or university contexts – this format provides valuable networking opportunities as well as furthering ACELL's community of practice aims. These assignments deliberately forced delegates to move beyond their comfort zone by testing some experiments in areas outside their fields of sub-discipline expertise. In this way, the evaluation of each experiment drew on some specialist expertise, whilst still allowing staff plenty of opportunity for insight into experiments from the student perspective.

Evaluation methods

The February 2006 ACELL Workshop was held over 3 days and involved 33 staff (excluding the 8 Project Directors) and 31 student delegates from 27 tertiary institutions across Australia and New Zealand. All delegates were surveyed extensively during the workshop for their views on the chemical and educational aspects of the 33 experiments they tested, and again at the very end when their evaluation of the workshop itself was sought – this evaluation is the focus of the current report.

Staff delegates were asked to respond to eleven 5-point Likert scale items while student delegates were asked to respond to six 5-point Likert scale items; there were four common items. All delegates were also asked for responses to four open-ended items. Together, the delegate responses provide a rich vein of both quantitative and qualitative data against which to assess the efficacy of the ACELL workshop format in achieving the project's aims. Where appropriate, the distributions of responses to the Likert-scale items have been compared using non-parametric χ^2 hypothesis 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 homoscedastic two sample *t* tests to compare means.

The four open-ended items included in the survey were:

- What did you find to be the most valuable aspect of the ACELL 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 entered into a database as thematically distinct comments prior to being subject to a content analysis, where each and every comment was coded into one or more of six broad categories, corresponding to three 'researcher' and three 'native' categories. Most comments were allocated to one category only; however, on occasion a given comment was included in, at most, two categories. Once categorised, all comments were identified as being either a 'positive' or a 'negative' response to facilitate statistical analysis. The six broad categories, together with their coding type, and number of positive and negative delegate responses are listed in Table 1; findings from these categories will be highlighted in the discussion section of this paper.

Table 1. Broad coding categories used in the content analysis of delegate responses to open-ended items, together with the number of staff / student positive / negative responses in each category

Category / Code	Staff Comments			Student Comments			Grand Total
	Pos.	Neg.	Total	Pos.	Neg.	Total	
Delegate Interactions	14	2	16	18	1	19	35
Educational Aspects	33	3	36	34	8	42	78
Workshop Design	7	17	24	12	22	34	58
Project Design	2	6	8	3	4	7	15
Project Impact	16	0	16	7	0	7	23
Miscellaneous	4	2	6	3	0	3	9

Feedback collected arises from different methodological frameworks, and includes quantitative (hard), coded qualitative (medium-textured), and verbatim comment (soft) data – in order to interpret and reconcile these different data sources, methodological triangulation has been used (Denzin and Lincoln 1994). Triangulation allows data interpretation which better reflects the actual experiences of the delegates, providing a deeper understanding than would otherwise be possible (Sidell 1993).

Results and discussion

Delegate Interactions (DI)

Staff and student delegates were each asked one Likert-scale item within the DI category (Figure 1); these were designed to interrogate how each delegate group's perceptions of the other had changed as a result of their workshop participation, and a strong positive response is evident. Responses to item 1 highlight (*i*) an increased student-delegate awareness of the commitment of academic staff to improving student learning, and (*ii*) a greater appreciation of the effort involved in developing an effective laboratory learning exercise. These data also imply a significant improvement in the personal development and attitudes to learning of student delegates following the workshop, and suggest that their greater awareness of staff commitment to improving laboratory learning can enhance the quality of the student reviews of experiments submitted to the project. Item 2 was designed to gauge the level of impact of the workshop on staff-delegate professional practice; the response unambiguously highlights that staff had forgotten what it is like to be a student, making it difficult for them to judge the quality and effectiveness of experiments from the student perspective.

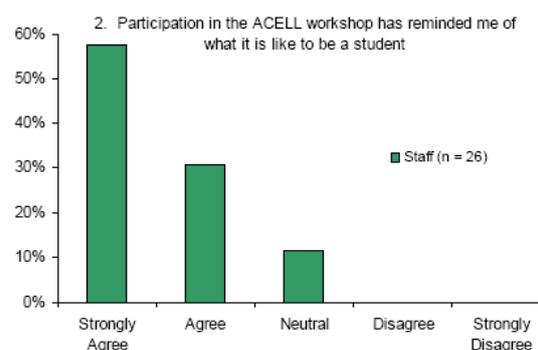
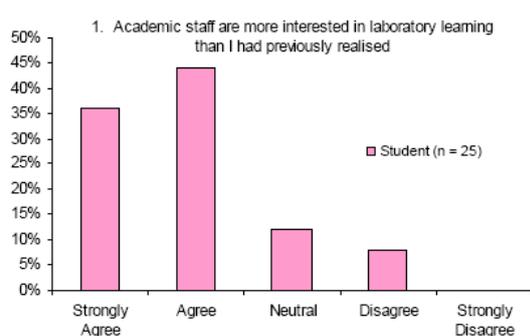


Figure 1. Delegate responses to their respective Likert-scale items on delegate interactions

Delegate responses to the open-ended items in the DI category cover themes including ‘delegates’ perceptions of one another’, ‘personal / professional development and networking’, and issues of ‘discussion, collaboration and feedback’. As shown in Table 1, both students and staff provided responses that are significantly more positive than negative in this category ($\chi^2 = 24.2$, $df = 1$, $p = 8.64 \times 10^{-7}$). The positive nature of the delegate responses is in accord with the quantitative data presented in Figure 1, and the following comments (made when commenting on the most valuable aspect of the workshop) illustrate the nature of these positive impacts:

Staff: “Interactions with people – it widens your network and provides you with opportunities to talk to people about lab development.”

Student: “Being able to give feedback on the labs as a student. It was a rare opportunity and I did not realise how interested the demonstrators were in student opinion.”

Student: “I enjoyed the interactions between the staff and students. It was good to see the views of the staff. I was fascinated by what they had to say.”

Educational Aspects (EA)

Figure 2 presents delegate responses to two items which examine their development of educational awareness as a result of participating in the ACELL workshop. Both staff and students report an overwhelmingly positive improvement of their understanding of educational issues (Question 3); on the +2 to -2 scale, the mean student response of +1.64 ($\sigma = 0.49$) is slightly more positive ($t_{49} = 2.12$, $p = 0.0388$) than the mean staff response of +1.31 ($\sigma = 0.62$). Student responses to Question 4 (concerning the amount of effort involved in laboratory design) shows a significantly more positive response pattern ($\chi^2 = 12.3$, $df = 2$, $p = 2.11 \times 10^{-3}$), suggesting that the student cohort has gained an increased awareness compared to the staff delegates, and this stronger level of agreement amongst the students is indicated by significantly higher ($t_{48} = 3.62$, $p = 7.01 \times 10^{-4}$) response mean of +1.42 ($\sigma = 0.78$) compared with that of +0.58 ($\sigma = 0.86$) for staff on the +2 to -2 scale. This minor divergence of views is not surprising and is most likely attributable to the lack of prior exposure of students to issues surrounding educational awareness, also seen in an increased student awareness of the teaching content of laboratory exercises – more than 80% of student delegates agreed or strongly agreed that laboratory exercises are intended to teach more than they had previously realised. The previous APCELL participation of some staff delegates may also contribute to this difference.

Staff delegates also responded to items concerning the importance of developing theoretical and conceptual knowledge, scientific and practical skills, thinking skills, and generic skills through laboratory exercises – they agreed or strongly agreed that their awareness in each of these areas had increased at rates between 50% and 70%, providing further evidence that the workshop constitutes a powerful professional development tool to assist in improving student laboratory learning outcomes.

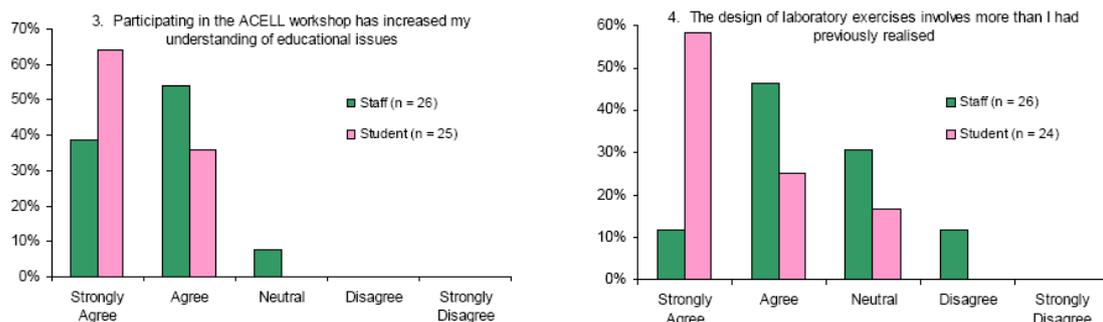


Figure 2. Delegate responses to two Likert-scale items relating to the educational aspects of the ACELL workshop

Delegate responses to the open-ended items in the EA category cover themes including 'delegate educational awareness', 'quality/effectiveness of laboratory exercises for improving learning', and 'reflection and reflective practice'. Both student and staff responses in this category are significantly more positive than negative ($\chi^2 = 41.1$, $df = 1$, $p = 1.45 \times 10^{-10}$), with no significant difference between the response patterns of staff and student delegates ($\chi^2 = 1.84$, $df = 1$, $p = 0.175$). Examples of positive comments (relating to the most valuable aspect of the workshop) include:

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: "Most of all though, I was shocked to find that the academics at the universities really want to make our laboratory experience as worthwhile as possible."

Student: "That was one of the best chemistry experiences I have had in the last 4 years – knowing that there are people that are concerned with teaching in labs and what makes a great lab and how they can be improved has given me ideas that I can take back when I demonstrate students."

Workshop Design (WD)

Negative comments within the EA category typically concerned the group size in the morning sessions – as one student put it, 'smaller groups facilitate an open discussion'. Within the Workshop Design (WD) category, many of the negative comments raised concerns about the acoustics in the hotel hosting the evening debrief sessions. Both of these types of criticisms are constructive, showing a high level of engagement with the process, and were almost uniformly made in the context of suggested improvements; they should be understood in the light of overwhelmingly positive feedback on the workshop as a whole (Figure 3). There was uniform agreement on both the value of the workshop for improving laboratory learning, and on its personal value for delegates – given that delegates devoted five days to the workshop (including travelling), their enthusiasm at the end of it (and some expressed interest in future workshops) is a testament to the value of ACELL.

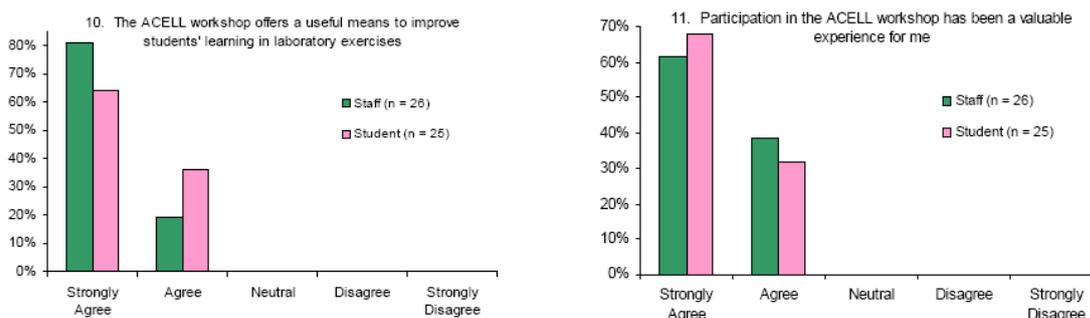


Figure 3. Delegate responses to two Likert-scale items relating to the design of the ACELL workshop

Conclusion

The A(P)CELL model has proved effective at engaging academic staff and students in a collaborative exercise; its methods could be easily applied in other disciplines such as biology, physics, or engineering. The immersive workshop approach allows discussion of both pedagogy and discipline content, it engages staff in a scholarly approach to curriculum development, and provides a practical way for student feedback to be used in designing resource intensive activities. The community of practice network established at the workshop

continues to collaborate, whilst the materials provided on the ACELL website provide ongoing professional development. The institution level implications of the ACELL approach to formally articulating the purposes of laboratory work are being explored.

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