Information about the ACELL Educational Template

The ACELL 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 *ACELL Educational Template*. The Educational Template sets out the educational objectives of experiments included in the ACELL 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 ACELL database with evidence that the experiments are high quality learning resources.

The template is divided into five sections, which present:
(1) a general summary;
(2) an analysis of the educational objectives;
(3) student experiences;
(4) documentation; and,
(5) peer review criteria for acceptance to the database.
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 ACELL 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 ACELL 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 ACELL workshop, or at an institution other than the submitting institution. Feedback will be provided after this testing phase, which may lead to modifications of these sections. ACELL 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 criteria listed in section (5)) prior to an experiment being included in the ACELL 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.

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.

PEER ASSESSMENT CRITERIA: The final section shows the criteria used during peer assessment of submissions; submitters should used this section to self-assess their submissions.

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.

Section (1.3) 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 (1.4) will be used within the ACELL database to assist in searching for experiments. At most two chemistry domain keywords should be chosen from the following list:

- Analytical chemistry
- Biological chemistry
- General chemistry
- Inorganic chemistry
- Organic chemistry
- Physical chemistry
- Theoretical 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 ACELL experiments in the future.

Section (1.5) 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. Estimations of time students will require before, during, and after the experiment are included in section (1.6).

Full details for all authors are listed in section (1.7). These are the authors of the educational analysis, and submitted the experiment to the ACELL database; no claim of authorship of the experiment is made in section (1.7).

Section (1.8) 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 ACELL 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 (1.7) are responsible for the educational analysis of this experiment, their submission of it to ACELL 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 (1.9) 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. References should be included in section (1.10), 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 four categories: *Theoretical and Conceptual Knowledge*, *Scientific and Practical Skills*, *Thinking Skills*, and *Generic Skills*. 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. The third category, thinking skills, can be considered as a subset of the generic skills category; however, development and practice of thinking skills are frequently fundamental to the analysis of laboratory results, which warrants them being considered separately.

The template requires that each outcome be labelled as **I**, **D**, or **P**, which stand for Introduction, Development, and Practice, respectively. This recognises that knowledge in some areas, and many skills, take considerable time to develop. As a consequence, one activity might have a goal of introducing an idea or a technique (**I**), where another aims to develop a skill by applying it to a new problem, or into a new area (**D**). Taking the skill of report writing as an example, if a report is simply marked, with only a general comment provided, then the student is practicing the skill (**P**). By contrast, if detailed feedback is provided, which is then applied to the next report, or if a re-submission and re-marking process is available, then report writing skills are being developed (**D**). It is recognised that some laboratory exercises could be described with more than one of these labels; in such a case, more than one category label should be used. Submitters should be aware that the label chosen will influence responses in the indicators column. For example, if an outcome was to introduce students to the techniques of titrations, then completing one or more titrations would be a sufficient indicator for students; if the outcome was to develop their technique, then the indicator would need to provide the student with evidence of an improvement in their skills. Indicators of skill development may extend beyond any single experiment, and relate to the entire practical program, or to its assessment methods. For example, if oral assessments, at which reports are discussed, are included in a practical program, this would allow

report writing skills to be developed without detailed written feedback being provided. Factors such as these which influence indicators should be included in the educational analysis.

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 Skills*, 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 Skills:

Generic skills 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. ACELL 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 ACELL 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

- **Workshop Notes**, section (4.4), 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 (4.5), 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.

Section 5 – ACELL Peer Review Criteria

The following are the criteria against which the submission will be peer assessed, and should be used to self-assess your submission.

Template Component	Criteria	Indicators	Criteria met? Yes/No
Section 1: Summary	The summary provides an accurate overview identifying high student relevance and interest	▪ How the experiment relates to other course content is clearly specified ▪ Prior knowledge clearly stated ▪ Alternative applications and possible modifications are identified ▪ High relevance to student learning needs clearly stated ▪ Practical and feasible to implement	
Section 2: Educational Analysis	The educational analysis provides a sound rationale for the experiment effectively contributing to high quality student learning processes and outcomes	▪ The experiment is student focussed with attention paid to how students will learn by participating in the experiment ▪ Appropriate learning outcomes are clearly stated, and are appropriately categorised as **I**ntroduction, **D**evelopment, or **P**ractice ▪ The teaching and learning activities effectively support the achievement of the stated outcomes ▪ The indicators relate to the stated learning objectives ▪ The indicators clearly specify how both staff and students will know whether the learning outcomes have been achieved	
Section 3: Student Learning Experience	Student evaluation indicates that the experiment was an effective learning experience from the students' perspective	▪ Key features indicating a high quality student learning experience have been summarised from the student feedback ▪ The students indicated the learning outcomes were relevant ▪ The students identified that the activities in the experiment contributed effectively to their achievement of the learning outcomes ▪ The student notes effectively supported student learning	

Section 4: Documentation	(1) **The Student Notes** effectively support student learning by, clearly communicating intended outcomes, explaining teaching and learning activities, and specifying assessment criteria	▪ Learning outcomes are clearly communicated ▪ Learning tasks that students will engage in are clearly explained ▪ Useful indicators that students and staff can use to monitor student learning of the stated outcomes, are clearly communicated ▪ Experimental procedures are clearly described ▪ The notes support students in taking responsibility for their own learning	
	(2) **The Demonstrator Notes** support demonstrators in teaching effectively by clearly communicating the intended outcomes, explaining the teaching and learning activities, and specifying the assessment criteria	▪ Learning outcomes are clearly communicated ▪ Learning tasks that students will engage in are clearly explained ▪ Effective teaching strategies that demonstrators can use to support student learning are included ▪ Useful indicators that students and staff can use to monitor student learning of the stated outcomes, are clearly communicated ▪ Experimental procedures are clearly described ▪ The notes support demonstrators in facilitating independent active student learning	
	(3) **The Technical Notes** support technical staff in efficiently setting up and dismantling the experiment	▪ Equipment is accurately specified ▪ Clear set up instructions are provided ▪ Relevant safety issues are noted	
	(4) **Other Documentation**	▪ Any other documentation is accurately described and appropriate for its purpose	