ASELL Advancing Science by Enhancing Learning in the Laboratory

Information about the ASELL Educational Template

The ASELL project aims to improve the quality of learning in undergraduate science 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 domain keywords should be chosen from the following list:

Biological Sciences

- Biochemistry and Cell Biology
- Ecology
- Evolutionary Biology
- Genetics

- Microbiology
- Physiology
- Plant Biology
- Zoology
- Other Biological Sciences

Chemical Sciences

- Analytical Chemistry
- Inorganic Chemistry
- Macromolecular and Materials Chemistry
- Organic Chemistry
- Physical Chemistry (incl. Structural)
- Theoretical and Computational Chemistry
- Medicinal and Biomolecular Chemistry
- Other Chemical Sciences

Physical Sciences

- Astronomical and Space Sciences
- Atomic, Molecular, Nuclear, Particle and Plasma Physics
- Classical Physics
- Condensed Matter Physics
- Optical Physics
- Quantum Physics
- Other Physical Sciences

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.

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.