Examples from Australian universities

Inquiry Based Laboratories for Learning in Biology; Throwing away the Cookbook

Associate Professor Pauline Ross
University of Western Sydney

Broad discipline area:
Natural and Physical Sciences
- Biological Sciences

Year level:
- First and Third Year Undergraduate

TRN strategy:
- Teaching research methods, techniques and skills explicitly within subjects
- Building small scale research activities into undergraduate assignments

Teaching and learning context:
- Research lab work
- Practical experiments
- Field trips
- Assessment (assignment)

Brief description of the initiative:
Rationale
Practical classes have a long history of being viewed as integral (Hodson, 1990, 1998), to the process of teaching and learning in the Sciences, because it is here that academics and students alike believe that "Science is done". Many practical lessons at tertiary level direct students to follow a series of specific steps, rather like the steps in a recipe or cookbook (Fraser and Deane, 1999) and end in a "rhetoric of conclusions" (Schwab 1962), as opposed to being investigatory or inquiry. In a reaction to this, there has been a movement to 'inquiry-based' practical lessons in more recent years (Lawson 2004). However, antagonists of this "inquiry, investigatory" approach argue that it is fraudulent, requiring students to reveal the truth of theorems which had often taken scientists an entire life time to elucidate or were the result of centuries of work and thought, such as some of the principals of motion, matter and energy, or the molecular nature of photosynthesis (Ross et al, 2006). Proponents of the recipe approach also applaud the time-efficient nature of a recipe practical, especially for students with limited laboratory skills and low tertiary

entrance scores, but recipe practicals give students little opportunity to work out for themselves why things went wrong, thus denying them the experience of the scientific method and the opportunity to develop skills in critical thinking. Despite the consistent outcry that inquiry and investigatory learning approaches are needed in Science curricula (Tytler 2007) , based on arguments which are now half a century old (e.g. 1960s Nuffield reforms, Bruner 1960; Schwab 1958, 1962) the status quo remains. The only crack in the tertiary dam wall, in recent years, has been the use of inquiry and investigatory practical laboratories for some types of investigations at tertiary level, most commonly fieldwork exercises and in final year units.

The methodology

In 1998 at the University of Western Sydney, the team focussed on creating an inquiry/investigatory, research-based environment through the development and introduction of:

- Investigatory-based practical laboratories, engaging 40 to 500 students from first to third year. This meant throwing away the traditional recipe, cook book laboratory manual and re writing practical laboratories using an inquiry framework
- Independent learning investigations

The initiative

(a) Inquiry-Based Laboratories

Strategies were developed to encourage students to collaboratively design experiments, test hypotheses, gather data, make mistakes and develop critical thinking and communication skills by reporting the results of their experiments to their peers.

These experimental protocols are designed mainly for the laboratory, but also for field work. These are structured in 3 stages; exploration, investigation and reporting. In the exploratory stage students identify a hypothesis and design an experiment to test the hypothesis, including a selection of appropriate methods. The selection of appropriate methods can create a barrier to student progress because students may not as yet have developed an appropriate repertoire to draw from, particularly at first year. Therefore, technical notes were written to support student investigations within the context of the investigation. In the investigatory second stage, students carry out their experiment, collect and analyse results. In the final reporting stage, students present their results verbally or in writing to their peers. These collaborative learning sequences de-emphasised the correct absolute result and immediately provided an engaged, authentic, professional scientific context for discussion about what may have gone wrong or what could be improved. Students were then assessed on the process and the product, rather than on the correct answer.

(b) Independent learning investigations

The scientific method was used as a basis for independent learning investigations done at home using the same methodologies modelled within the practical laboratories. Students (up to 500 in first year) were set an inquiry, problem based, research-infused task. An example of this included a task to determine the effects of bushfires (simulated through smoking and heating) on seed germination. To do this inquiry task, students explored the research on the topic, formulated a hypothesis, designed an experiment, waited for seeds to germinate, collected, analysed the data and then situated the results of their experiment within the broader research literature on the impact of heat and smoke on seed germination. The final stage required a written draft report to be submitted for feedback, before the submission of a final report. Students only did this following a workshop in which they had an opportunity to critique model scientific reports from previous years. Receiving feedback on their draft report meant that they generally felt more confident and knew what they had to do to be successful in the unit. It was unlikely they would be perfect the first time and they needed to be confronted and corrected (Biggs and Tang, pg 102, 2007). This also modelled the process of peer-review of a journal submission.

Evaluation

The learning outcomes from these activities were for students to:

- analyse and integrate ideas from the scientific literature to create a story and a rationale for a scientific experiment or investigation;
- formulate a scientific hypothesis for investigation;
- design and conduct a scientific investigation or experiment to test the hypothesis;
- use scientific conventions to produce a report that communicates data, trends and results arising from a scientific investigation or experiment;
- use scientific language to deliver an oral and written presentations on the analysis of data arising from a scientific investigation or experiment.

These learning outcomes are identified to students and integrated horizontally and vertically throughout the curriculum providing a basis of understanding of evidence-based practice in the Sciences being used in honours, postgraduate level and professional contexts. Although we have not specifically evaluated all the aspects described above, there were some challenges for staff and students. Academic staff have not, at all times, been comfortable with the open-ended nature of the laboratory and field work and students at the start, wanted to know the answer or the solution to the task and sometimes resist having to think. Once the open- ended structure has been experienced and practised, students feel secure and they become accustomed to thinking, rather than following a recipe. This enhances the development of critical thinking skills and helps both students and staff feels valued. Students have stated that the independent learning exercises were powerful experiences.

> *"The most useful task I undertook was the seed germination report. The process of drafting a report, handing it in for feedback and then having the opportunity to implement that feedback I found very useful and was then able to apply my learning from that tasks across to other subjects".*

Reference:

Biggs, J. & Tang, C. (2007) *Teaching for Quality Learning at University: What the student does* (2nd edition) Berkshire UK Society for Research into Higher Education and Open University Press.

For further details:
Pauline Ross
University of Western Sydney
pm.ross@uws.edu.au

Handout/Teaching materials:
Available on request.