Evaluating enquiry-oriented experiments in a service subject

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Abstract: *Renewed interest in learning in laboratories and concerns about the relevance of the existing laboratory program prompted reconsideration of the role of enquiry-oriented experiences for biological and medical science majors at the University of Technology Sydney (UTS) who are required to enrol in a semester of physics. In this study, supported by the Australian Teaching and Learning Council, we explore the development and evaluation of enquiry-oriented experiments for these majors. The process by which experiments are developed and evaluated includes input from academics, senior students and demonstrators. We give substance to the process through its application to the creation of a new experiment. An aspect of the process focussed upon in this paper involves students drawn from the biological/medical sciences, who completed the subject in earlier years. These students were paired with demonstrators in the evaluation and on going development of the experiment. The results of trialling the new experiment are examined as are the perspectives that students and demonstrators bring to the evaluation process. Issues of relevance and context are shown as keys to the engagement of biological/medical science majors in physics experiments.*

Introduction

Many graduate capabilities, such as effective oral and written communication, working productively in groups, behaving responsibly and ethically in a professional environment, and devising and testing creative solutions to novel situations, can be developed in the laboratory. Not all laboratory experiences are likely to foster the development of such capabilities. For example, cookbook type experiments do little to stimulate students and are more likely to stifle the development of reasoning and ingenuity capacities (Bless 1933).

An enquiry-oriented approach to physics experiments for large cohorts of first year engineering students was introduced successfully at UTS in the late 1990s (Kirkup, Johnson, Hazel, Cheary, Green, Swift and Holliday 1998). This approach was extended to a first year physics service subject called Physical Aspects of Nature (PAN). PAN provides an introduction to physical principles and is presented with a particular focus on applications in the bio/medical sciences. Concerns were expressed by students about the PAN laboratory program particularly in relation to the context and relevance of the experiments undertaken, first informally, then through end of semester surveys.

Methodology

To assist in the development of experiments, first hand experience was obtained of the discipline areas from which the students were drawn. This was done primarily through attendance by one of us (LK) at lectures in subjects that form part of the students' majors. This permitted identification of explicit and implicit links between the majors and physics which could be exploited, for example, in the development of new experiments. Stakeholders involved in the development and evaluation of experiments were current and 'ex' PAN students, demonstrators, academics from the Department of Physics and Advanced Materials, academics from the bio/medical science disciplines and teaching and learning specialists at UTS. Evaluation of the experiment at several stages was a feature of the development. A focus was brought to the educational analysis of the experiments and was influenced by work of the group: 'Advancing Chemistry by Enhancing Learning in the Laboratory' who have established a thorough methodology for the evaluation of chemistry experiments (Buntine, Read, Barrie, Bucat, Crisp, George, Jamie and Kable 2007).

The iterative process of developing and evaluating an experiment is outlined in Figure 1, with informal feedback, surveys and focus groups used as the basis for revising the experiment.

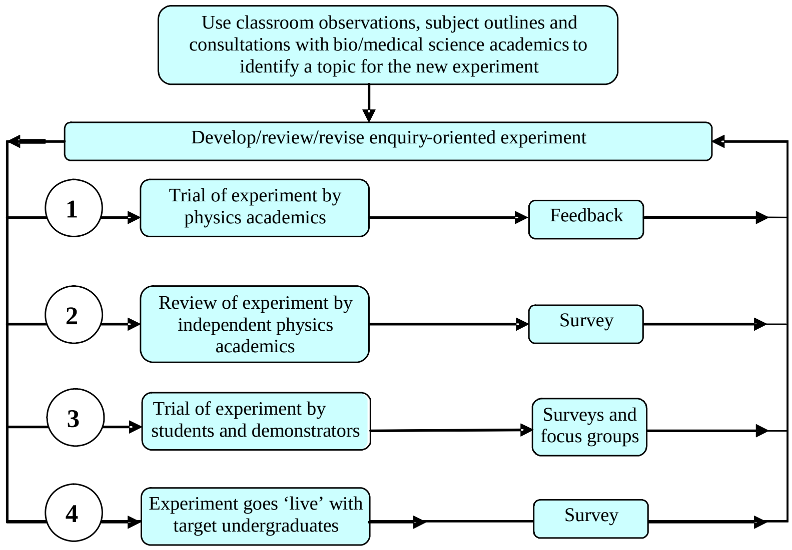

Figure 1. Flow diagram of trialling, evaluating and revising an experiment

Step 1 is characterised by informal feedback on technical aspects of the experiment including whether there is a good match between prework that the student is required to do and the experiment itself. In Step 2, physics academics with no direct involvement in the experiment assess the materials created for the experiment. Step 3 involves recruiting students who are majoring in the bio/medical sciences and who have already completed PAN. Inviting such students to be part of the development process allows for an informed, student centred, and 'hands-on' review of an experiment and brings issues of context and relevance to the fore. Physics demonstrators, who have had no input into the design of the experiment, are recruited to give another perspective on the experiment. Students and demonstrators work together on the experiment as equals. In Step 4, the experiment is undertaken by students enrolled in the subject as part of their normal studies.

Details of the experiment

In order to give substance to the approaches adopted, we give a brief account of the development and evaluation of a new experiment designed for PAN.

Through attendance at lectures, it was evident that fluid flow is an area of value and relevance to bio/medical science students at UTS. As a consequence, this area was chosen to form the basis of an experiment. The experiment happens at a point in the PAN laboratory program where the nature of the experiments shifts from a focus on key skills (such as the quantification of errors) to a greater emphasis on enquiry. In terms of the level of enquiry as described by Hegarty (1978) the experiment would be classified as level 2a in which the aim is given, materials are given in whole or in part, the method is open or partly given, and the answer is open. Figure 2 shows the stages of the experiment and those activities that have an enquiry orientation.

Evaluation of the experiment

Bringing seven students who had completed PAN in a previous semester and four demonstrators together was a pivotal step in the development and evaluation process and we now focus on this. As far as possible, students and demonstrators were paired together, with only one group consisting solely of three students.

Survey administered to students and demonstrators

The survey included 12 statements requiring responses on the Likert scale of strongly disagree (score of 1) to strongly agree (score of 5) and two open-ended questions; 'What were the strengths of this experiment?' and 'How could the experiment be improved?'.

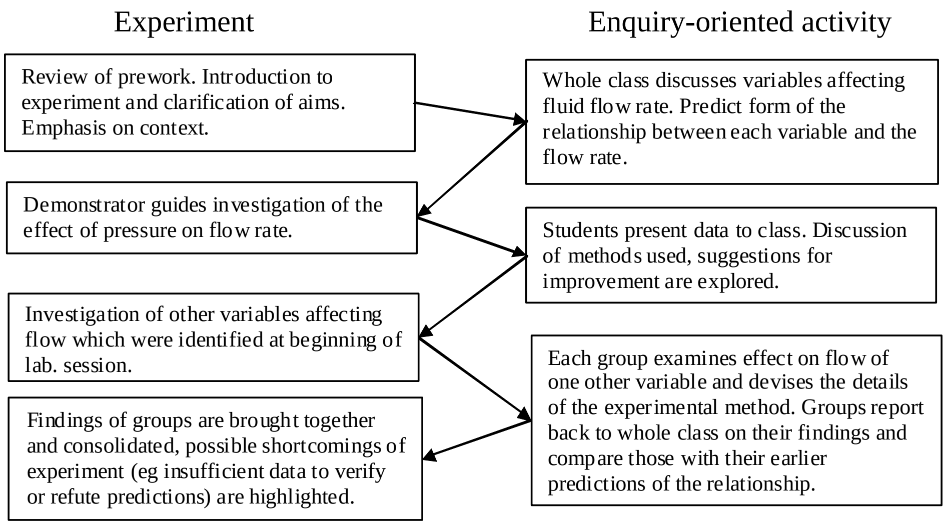

Figure 2. Stages of the experiment and related enquiry-oriented activities

Seven from seven students commented positively on the 'relevance to real life' or the 'relationship to health and physiology subjects'. In contrast, the most prevalent positive comment from demonstrators was of the 'simplicity of the experiment'. With regard to improvements that could be made, students emphasised that still more could be done to improve context (3/7) (eg by introducing 'animations of blood flow at the beginning of the laboratory session') while demonstrators suggested there be more data collection and analysis opportunities (2/4).

Figure 3 shows the survey statements. The average for most statements lies close to the agree level with demonstrators on the whole slightly more positive than students. Two averages were close to neutral. The first of these, relating to time management skills, reflects the fact that the time keeping in the experiment was closely monitored by the 'demonstrator in charge', thus deemphasising the need for students to practice (or be aware of) such skills. The second close to neutral score relates to the statement 'notes for students should include more detailed instructions'. We take this score as a measure of success of the experiment, as the intention is to empower students to devise the experimental method themselves.

At the conclusion of the experiment, students and demonstrators took part in separate focus group sessions. This allowed both groups to bring their own perspective to the trial, and eliminate the possibility of one group dominating the session.

The focus groups revealed that students were perhaps more secure with the open ended aspects of the experiments than the demonstrators. For example, when asked: 'Do you want the demonstrators to tell you exactly what to do?', the consensus was 'No' and is typified by the reply:

> '- it makes you think,.. You understand what's going on but you have options. It's open to interpretation, you can do it this way or that way. You may see disadvantages that the demonstrator may not.'

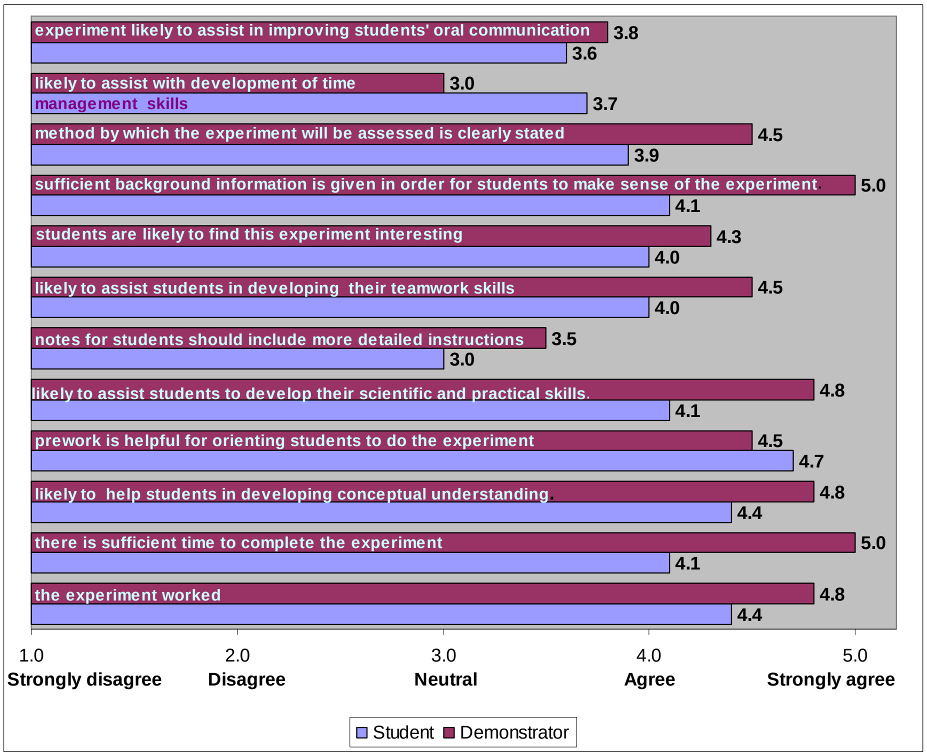

Figure 3. Student and demonstrator responses to survey questions

Conclusion

A process has been outlined for the development and evaluation of enquiry-oriented experiments for a physics service subject which incorporates the input of key stakeholders. An essential element of the process, in which students who have completed the subject in a previous semester are paired with demonstrators to trial an experiment, offers valuable insights into the values, expectations and experiences of both students and demonstrators. The benefits of having both groups working together 'as equals' in the laboratory deserves to be explored further, as each bring perspectives which may be of strategic value when preparing future students and demonstrators for the challenges of engaging in, and facilitating, effective learning through enquiry-oriented experiences. We also remark that there are facets of the process which may be of value in the evaluation of experiments beyond those designed for students enrolled in service subjects.

Students and demonstrators viewed the experiment reported here positively and the feedback has led to revision of the experiment. The experiment effectively engaged the students and this was in large part due to context chosen which was appealing to students drawn from the bio/medical sciences. Student emphasis on 'relevant context' was as striking, as it was expected. Perhaps surprisingly, the enquiry-oriented elements of the experiment attracted more positive comments from students than demonstrators, pointing to demonstrator comfort with enquiry-oriented experiments as an issue requiring further examination.

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