Mixing knowledge, attitude and experience–teamwork approach in the 1st year undergraduate physics laboratory

Marian W. Radny and **Aime B. Duval**, School of Mathematical and Physical Sciences, University of Newcastle
marian.radny@newcastle.edu.au aime.duval@newcastle.edu.au

Abstract: *We report on a new laboratory program implemented in the first year, lower-level service physics course at the University of Newcastle in 2005. It is shown that the new laboratory environment has resulted in very high overall students' satisfaction for the new program and positively influenced the way they look at their laboratory-based learning experience. In particular it is shown that their study approaches have been influenced in a positive manner, with students acknowledging that the new laboratory structure has developed their teamwork skills and helped them to better understand the lecture material and the underlying physical principles.*

Introduction

The traditional-style introductory physics laboratory has been known to be ineffective in undergraduate physics teaching (e.g., Wilson and Hunt 2002), and some improvements to the laboratory programs have been proposed. These include problem solving models (Heller and Heller 2002), 'challenge' type experiments (Mills, Feteris and Greaves 2004), extensive use of technology (Technology Enabled Active Learning - Belcher 2001) and more radical schemes such as a guided discovery approach with lectures replaced by supervised workshops (Redish 2002). While most of the proposed schemes employ a student-centred approach and emphasise small group learning activities there is, however, no agreed understanding on what type of questions should be asked and/or what kind of students' behaviour should be observed in the laboratory activities accompanying introductory physics courses, especially those classified as service courses.

In this paper we discuss an approach aimed to explore whether a typical laboratory framework is able to deliver some teaching/learning benefits other than developing just typical laboratory skills such as practical skills, experiment design, etc. In the context sketched above our approach can be termed conservative. We will show, however, that by progressively supplementing lecture materials and extensively promoting teamwork, the proposed program enables a practical and effective way of engaging students into the course (not just the laboratory). The three main ingredients of the newly developed laboratory scheme, i.e., supervised pre-laboratory assignments, experimentation, and completion of the final laboratory report, were designed to promote collective work based on an assumed knowledge of relevant lecture materials and the new laboratory experience. As such the proposed scheme fully respects students' abilities, knowledge and experience, providing a net of 'respectful' facilities (Logan 2005) to help students. The scheme also makes the students aware of the standards expected of them and maintains the quality of the subject.

Changing the laboratory environment

The School of Mathematical and Physical Sciences at the University of Newcastle (UoN), like many physics departments in Australia and world-wide, runs preliminary (introductory) physics courses for non-physics oriented students wishing to undertake undergraduate studies in fields such as Biomedicine, Biotechnology or Engineering. Such courses are usually termed physics service courses. First year, non-physics oriented students at UoN undertake a lower level physics service course which extends over thirteen weeks, and consists of four-hour/week of lectures/tutorial and an eight-week laboratory program. In 2005 the laboratory program for this course was significantly changed in line with the changes introduced progressively into our 1st year introductory physics courses in previous years. The objectives were to promote self-confidence and effective learning

(Radny and Duval 2004), and positive attitude to physics among non-physics oriented undergraduate students (Radny 2004). The new laboratory program has been designed in particular to eliminate the common notion among students that the practical course work is alienated and an irrelevant part of their course learning experience, but also to encourage a team-based approach to problem solving.

The program is based on eight laboratory sessions over an eight-week period in the semester (13 weeks). In order to accommodate all the necessary changes, the topics were rearranged to fully align the laboratory activities with relevant lecture materials, with some new laboratory exercises written and some adopted from existing experiments. A previous emphasis on pre-laboratory home-based preparation has been reduced and partially replaced by an introduction to the laboratory (presented by the teaching staff), and a supervised pre-laboratory assignment. This is followed by typical laboratory tasks (data collection and analysis), and work on a final report. A session time of 3 hours is allocated to give students enough time to complete their prescribed laboratory activities, including their work on the final report (last 60 min of the laboratory session).

The introduction is presented to the students at the beginning of each session (10-15 min). Students may take notes and use them when working on their subsequent pre-laboratory assignment (15-30 min). Data collection and analysis usually take 60-90 minutes. Students work in groups of three and are encouraged to ask questions and discuss the assignment/laboratory tasks with the teaching staff and fellow students. The results from the laboratory activities (laboratory assignment, data collection and analysis) are recorded by students individually in a section of the laboratory notes which is set aside for that purpose, and are used as part of the assessment. Detailed feedback on all the assessed items is included in the marking scheme to guide students towards their final task, namely the laboratory final report which is written collectively within each group. All the assessed laboratory activities - except the final report - are marked progressively during the laboratory session.

The teamwork on the final laboratory report is the most significant move away from students' individual work in the laboratory. The key ingredients of the report are: a conceptual map of the underlying physical principles, summary of the experimental results, and discussion of the results (including answers to a number of open-ended questions). The conceptual map (linked diagrams or lists of information) is designed to help students identify what they have learned and what they still do not understand. The open-ended questions are designed to deepen understanding of the laboratory activities, facilitate critical thinking and spark team discussion. The assessment of the laboratory report includes a group assessment mark which amounts to approximately 30% of the total laboratory mark.

Evaluation of the New Approach

Analysis of satisfaction rates is based on 175 students who participated in the 2005 laboratory program. The students were given a questionnaire to complete (anonymously) in the last laboratory session of the semester. A 5-point percentage scale (strongly agree, agree, neutral, disagree, strongly disagree) was used in the evaluation. The questions asked and the respective responses were:

1. The laboratory program is an effective learning experience (12.1, 69.4, 16.2, 2.3, 0.0)
2. The lecture material and laboratory exercises are well integrated (11.4, 62.9, 22.9, 2.9, 0.0)
3. The laboratory program adequately supplements the course lecture material (12.4, 64.5, 20.1, 3.0,0.0)
4. The laboratory scheme effectively promote class participation and teamwork in the laboratory (24.7, 62.9, 11.2, 0.6, 0.6)
5. The laboratory sessions are well planned (9.9, 48.3, 32.6, 7.6, 1.7)
6. The grading of laboratory work is fair and appropriate (15.4, 60.0, 19.4, 4.6, 0.6)
7. My lecture-based knowledge has been sufficient for the laboratory exercises (4.0, 44.6, 35.8, 13.9, 1.7)

8. Introduction to each laboratory prepared me well for each laboratory session (11.6, 43.0, 36.6, 8.7, 0.0)
9. Lab Assignments prepare me well for each laboratory session (8.1, 46.2, 35.3, 10.4, 0.0)
10. Laboratory Experimentation (data collection and data analysis) help me to develop my practical and analytical skills (11.0, 65.3, 19.1, 4.0, 0.6)
11. Working on the laboratory final report effectively stimulates class/team discussion (13.2, 45.4, 32.2, 8.0, 1.1)
12. I have learned to think critically when working on my laboratory final report (5.2, 54.0, 35.6, 4.6, 0.6)
13. If needed, I feel I can discuss my problems with the laboratory teaching staff (45.4, 43.6, 8.6, 2.5, 0.0)

Students' responses to the new program were also categorised from three open-ended questions and the following categories of responses were identified (the most frequent first):

14. List up to three main challenges for you in the Physics 1000 laboratory in 2005:
Time - management/control; Mathematical - formulae/calculations/derivations; Error - calculations/analysis; Laboratory report; Understanding - questions/instructions; Graphs - plotting/conceptual maps.
15. List up to three of the most valuable things you got out of this laboratory program:
Teamwork – skill; Applying in practice – theory/lecture materia; Understanding – lecture material; Error analysis; Critical thinking; Time management.
16. In what way or ways (list up to three) was this laboratory different from the other laboratories in your first year at the University:
Teamwork; Final report – completed in lab/teamwork; Laboratory activities – harder/rewarding.

Discussion

The overall satisfaction rate for the new laboratory program was extremely positive, with 82% of respondents agreeing or strongly agreeing that the laboratory program was an effective and useful learning experience (2.3% disagree) – question 1.

Close integration of lecture course materials with the laboratory program is one of the core components of the new laboratory program and it was well received, with 74% of respondents agreeing or strongly agreeing that it was well integrated (questions 2). Only 49% of respondents, however, agreed or strongly agreed (16% disagreed or strongly disagreed) that the lecture material was enough for their laboratory sessions (question 7). The fact that 77% of students agreed or strongly agreed (3% disagreed) that the laboratory program adequately supplements the lecture material (question 3) suggests that the students appreciate expanding their understanding of the course materials by taking part in the laboratory program (question 10 - 76% agreed or strongly agreed that the laboratory helped them to develop practical and analytical skills).

Provision of effective collaborative work among students is the second core component of the new laboratory program and it was also extremely well received, with 88% of respondents agreeing or strongly agreeing that the new program was effective in this respect (question 4). Also, a large number of students indicated that development of their teamwork skills was the most valuable aspect of this laboratory program (question 15). As there are different levels of collaboration at different stages of each laboratory session we were particularly interested in students' response to their work on their laboratory final report, which was specifically designed to facilitate collaborative work and critical thinking. 69% of respondents agreed and strongly agreed (question 11) that their work on the final report encouraged class/team discussion. 60% agreed and strongly agreed that they had learned to think critically when working on the final report (question 12). The work on the final report was also assessed to be challenging (question 14) but rewarding (question 15). A large number of students indicated that time control/management was the most challenging aspect of the program. (some also indicated that this was a valuable experience). Regarding the student's learning needs, 89% of the respondents found (agree and strongly agree but not neutral) the amount of help was sufficient (question 13), and 75% agreed or strongly agreed that grading of laboratory work was fair and appropriate (question 6).

Future Directions

Students' feedback on the learning/teaching environment provided within the new program varied, with only 55% and 54% of respondents agreeing or strongly agreeing (9% and 10% disagreed, respectively) that the Introduction and Laboratory Assignment prepared them well for their laboratory exercises. This is not surprising as the informal feedback from students on their home preparation within the old as well as the new scheme indicates that the laboratory preparation is a very demanding and time consuming component of any laboratory program. Some changes to this part of the scheme will be considered for 2006. These will involve restructuring the contents of the introduction given by teaching staff at the beginning of each laboratory session, the supervised pre-lab assignments and the final report. Some changes to the time distribution in the laboratory will also be considered for 2006. The scope of some of the more challenging experiments will be addressed so that more time can be allocated to the analysis and interpretation of experimental data and the collective preparation of the laboratory report.

References

Belcher, J. (2001) Studio Physics at MIT. [Online] Available: http://web.mit.edu/physics/papers/Belcher_physicsannual_fall_01.pdf [2005, August 15].

Heller, P. and Heller K. (1999) *Cooperative Group Problem Solving in Physics*: Minnesota: University of Minnesota.

Logan, P. (2005) The missing factor for 1st year physics students? *Proceedings of the 16th National Physics Congress,* Canberra, ACT*,* 228.

Mills, D.R., Feteris, S.M. and Greaves, T.L. (2005) Developing Investigative Skills Through a 'Challenge' Experiment, *Proceedings of the 16th National Physics Congress,* Canberra, ACT, 228.

Radny, M.W. and Duval, A.B. (2004) Perception and effectiveness of an e-Grade online tutorial/assessment scheme in introductory physics courses, *CAL-laborate,* **12**, 19-24; [Online] Available: http://science.uniserve.edu.au/pubs/callab/vol12/ [2005, August 15].

Radny, M.W. (2004) Science learning environment – outside-class experience: Design, evaluation and challenge, *Proceedings of Scholarly Inquiry into Science Teaching and Learning Symposium, the 2004 National UniServe Science Conference,* Sydney, NSW: The University of Sydney.

Redish, E.F. (1999) Building a Science of Teaching Physics, *American Journal of Physics*, **67**, 562-573.

Wilson, K. and Hunt, M. (2002) First Year Teaching Laboratories: What's the Point? *Institute of Physics Congress,* Sydney, July 2002.