

Instructional Design Principles applied to Physics laboratory and tutorial courses

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Abstract. This study examines the effect on the learning experiences of students of changes to the running of laboratory and tutorial sessions of the first year auxiliary physics course at the University of the Witwatersrand, between 2001 and 2010. This research is underpinned by the principles of indirect interactive instructional skills and experiential learning. Two concerns drove this study: the first being a mismatch between the marks awarded to students for their laboratory reports, and their subsequent performance in formal practical tests. The second was the students' poor engagement – and hence performance in problem solving - during tutorial sessions. Several possible contributing factors were identified and changes were implemented in an attempt to improve the learning experienced by the students. Three sources of data suggest that the changes have had a positive effect on the learning of physics by the students in this course.

1. Introduction

The Physics I Auxiliary course is a non-continuing course aimed predominantly at Biology students - the class size varied between 300 and 600 students. The non-calculus curriculum has a balance between theoretical content and problem solving and is believed to be typical of algebra-based physics courses worldwide. The course is delivered by means of lectures, laboratory sessions and tutorials. Each student receives 180 minutes of lectures per week spread over four sessions, one 45 minute tutorial session per week and a three hour laboratory session every two weeks. In the alternate weeks, an additional one-hour tutorial session is held, followed by a one hour session in the computer aided laboratory (CAL) for underperforming students. In the CAL, the student can access interactive programs, with simulations and animations and can write either practice tests – with the aid of a tutor - or else formal tests for which marks are accumulated.

Laboratory Sessions: From 2001 – 2005, each student performed ten exercises during the course of the year. The laboratory manual contained a comprehensive description with detailed, explicit instructions on how to perform each exercise. The students recorded their data by filling in the blanks. Each laboratory session began with a 20 to 30 minute preparatory talk, given by the laboratory demonstrators, outlining in detail the various aspects of the experiment to be conducted. Most of the balance of the 3 hour session was dedicated to conducting measurements, data analysis and interpretation, the plotting of graphs and report writing. During these processes a fair amount of assistance was given by the demonstrators. In the final half hour of the session, the laboratory reports (defined as laboratory work within text to follow) were submitted by the students to the

demonstrators who were required to complete the assessment of the reports by the end of each session.

Concerns: Several authors [1,2] maintain that ‘cookbook’ activities are generally uninteresting, unchallenging and not engaging to the students. In addition to this criticism, we note that students were seldom well prepared for laboratory sessions – perhaps feeling that there was no need, given the detailed ‘recipe’ they had to follow. This led to a ‘robotic’ performance of the exercises with little understanding of the underlying principles - to compound this, laboratory demonstrators often gave too much assistance during the exercises. Also, sessions frequently ran overtime. Laboratory reports were poorly assessed because of the inadequate time allowed and as a result, laboratory report marks tended to be much higher than the corresponding laboratory test marks.

Tutorial sessions: Tutorials are arguably the primary learning activity of any first year Physics course, in particular for problem solving. In 1999, Heller and Heller [3] emphasised the importance of cooperative group work in solving text-rich problems. The guided discovery approach developed by Redish [4] and the Technology Enabled Active Learning program designed by Belcher [1] both highlight the importance of small group learning activities. Although at Wits we have long employed “small” group tutorial sessions, we continually seek to improve the effectiveness of learning activities. Prior to 2006, students were expected to prepare approximately 10 to 12 tutorial exercises on a particular section for a session. The tutorial questions were designed to complement the lecture notes and the lecture examples. The first 35 minutes of a session was a question and answer (Q&A) session in which the tutor helped students and gave feedback on their efforts. A tutorial test based on this section was then given during the last 10 minutes of the session. The tutorial group sizes varied between 25 and 35 students. Tutors were mainly postgraduate students who were supplied with solutions to tutorial questions together with guidelines of how to conduct the tutorial.

Concerns: Interactive learning was fairly non-existent in these sessions which generally resembled “recitation sessions” where tutors and to lesser extent students solved problems on the blackboard. It was also felt that groups were overlarge, students and tutors alike were inadequately prepared and there was a lack of interaction between students and tutors. Also there was no proper training for tutors who tended to give inadequate feedback to the students. In addition there were too many multi-level questions in the tutorial exercises.

2. Research question and Interventions

Will the implementation of simple improvements to the running of practical and tutorial sessions result in improvements in the learning of physics by first year students?

Practical Sessions: From 2006, the following changes were implemented: greater pressure was placed on students to prepare for the laboratory. During the first 30 to 45 minutes of the session, students were required to explore the apparatus and to attempt to set it up. This allowed them to ‘play’ with – and thus become familiar with - the equipment and hence to improve their confidence. Demonstrators were instructed not to assist the students with this process unless they ran into difficulty. They also monitored the progress of students during this part of the session and encouraged student engagement by mini-Q&A sessions. After this students conducted their measurements and wrote their reports. These were submitted at the end of the laboratory session and demonstrators had two weeks to assess the reports. This longer timescale for the assessment of reports resulted in reports being critically marked with substantial feedback and comments which had been lacking before. Also, the assessment of laboratory reports was monitored by the laboratory co-ordinator and the standard of the laboratory test matched that of previous years’ tests.

Tutorial Course: began with a reduction of the group size to a maximum of twenty during the fourth block of 2006. The tutorial sheets were revised to reduce the amount of conceptual overlap and duplication. This resulted in a smaller number of exercises (5 to 8) with escalating levels of difficulty. Preparation of selected material was made compulsory and tutors were required to provide feedback on the selected problems. A “floating tutor” was appointed to monitor individual students’ preparation. A full set of tutorial solutions was posted on the notice board after completion of each section of the syllabus. Tutors also attended regular meetings with the course coordinator at which concerns could be aired and roles clarified. A spot test is given during the last 10 minutes of the session to monitor individual performance on a weekly basis.

3. Findings

Below is a brief summary of the qualitative and quantitative data obtained from student’s performances and surveys based on changes implemented in the tutorial and laboratory courses.

Practical Sessions: Figure 1 shows a comparison of marks (%) accumulated for both the laboratory work and corresponding laboratory tests over a ten year period.

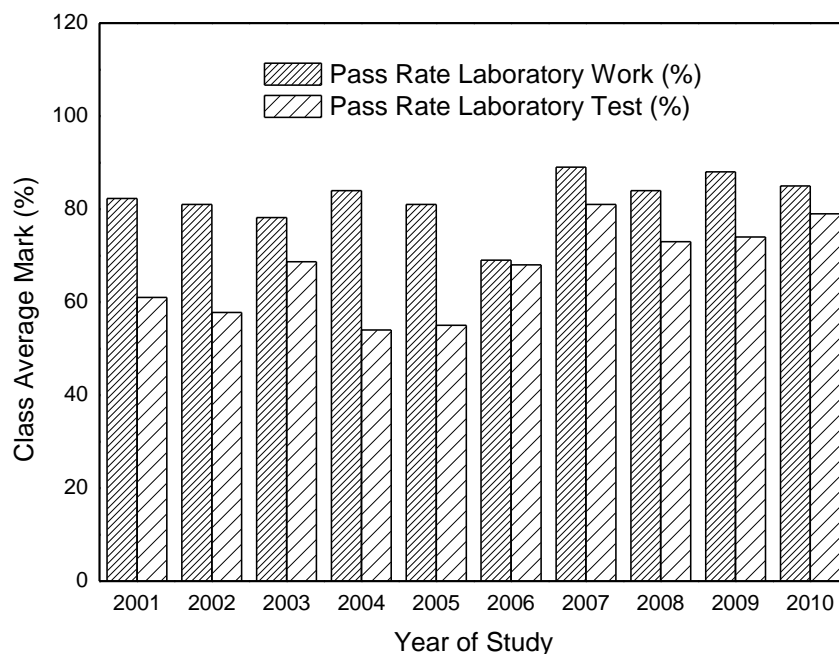


Figure 1: Comparison of laboratory report and test marks between 2001 and 2010.

During the period 2001 and 2005, the data shows on average approximately a 20% mismatch between the laboratory work and tests marks. This difference prompted the authors to investigate the reasons for the discrepancy in results. After careful consideration of a number of concerns highlighted above, it was tentatively concluded that a proper understanding of the aims of laboratory course was not fully achieved. In year 2006, the changes to the operation of the laboratory activities discussed above seem to show a better correlation between the laboratory work and test marks. Therefore these minor changes of indirect interactive instructional skills though far from ideal seems to be effective and has contributed to the improved experiential learning by students.

The validity of our results was tested by conducting a survey with the assistance of the Centre of Learning, Teaching and Development (CLTD) unit of the University in 2006. A questionnaire comprising four open ended questions was designed to ascertain whether there was evidence of improved learning. This survey was aimed at the laboratory demonstrators as the new students in 2006 could not have had any experience of the old dispensation. The responses of the demonstrators were quite strongly positive as illustrated below.

What impact has the modification of the laboratory structure had at these sessions?

- ✓ *Students are strongly encouraged to prepare (read in advance) for the laboratory prior to attending a session unlike other first year courses where the demonstrators give lengthy introductory talks.*
- ✓ *Students now understand that laboratory demonstrators are there to guide them instead of undertaking the majority of the laboratory work.*
- ✓ *They have realised that independent and group work is important when discussing and sharing experimental ideas.*
- ✓ *Their learning skills have improved which is reflected by their marks.*
- ✓ *Students have become more independent.*

How are the students responding to this format compared to the structure of other first year courses?

- ✓ *At the beginning of the year, it was not easy but they adapted and shown keen interest in the course.*
- ✓ *Students became very anxious about the apparatus and experiments and arrived early for classes.*
- ✓ *They realised that they were required to do extra work prior to the laboratory session.*

How has this change impacted on your demonstration skills?

- ✓ *This has improved my “co-operative learning”, problem identification, leadership and group work skills.*
- ✓ *I have developed a new way to test student’s skills and my own skills.*
- ✓ *This model allows us a new method to assess student’s understanding which improves the relationships between student and laboratory demonstrator.*

To what do you attribute the positive changes in the delivery of the course?

- ✓ *In the past, demonstrators used to do most of the laboratory work and students were lazy. Now students prepare well, understand the material, and are able to work independently.*
- ✓ *Students ask more questions during the sessions.*
- ✓ *The laboratory is now full of activity, more interaction between students and demonstrators.*
- ✓ *The structure of course is clear; students have a lot of flexibility in learning of equipment and measurements either independently or as a group.*
- ✓ *I feel that the change in structure, the small group sizes (less noise), and interactive classes has resulted in a good environmental for experimental work.*

Tutorial Sessions: Table 1 shows a summary of student responses based on a CLTD questionnaire which was administered to 96 students to assess their reaction to the changes.

Table 1: Student responses based on CLTD questionnaire.

Probe Questions	Positive Responses	Negative Responses	Neutral
How has the change in the tutorial structure (compared to the way it was done before) impacted on your work?	85	2	7
How have the tutors improved their delivery of feedback to tutorial questions?	70	16	10

A summary of the qualitative analysis of their responses is given below:

“The majority of students appreciated the enforced preparation prior to tutorials which enables them to obtain answers to their problem questions. They comment that the new system allows them to focus better and that much more is achieved in tutorial sessions. There is a sense that students enjoy taking some responsibility for their learning experience. It seems there are different standards of teaching skills amongst the tutors and also some communication and language issues. Overall the new system seems to be popular and well received by students.”

4. Conclusions and Implications

There seems to be evidence of improved learning in both the laboratory and tutorial components of this course - the students are more confident and better able to solve problems. The mismatch between their laboratory report marks and their laboratory test scores has been reduced and their performance in the laboratory test has improved. Some ideas for the future include a redesign of the laboratory manual is envisaged with the aim of introducing new fundamental experimental work which students can relate to everyday experiences. It will also be useful to conduct ongoing tutorial and laboratory course evaluations to monitor the success of innovative modifications made to a particular component(s) of the course. The postgraduate students who serve as tutors have limited teaching experience. Therefore, it is imperative that future modifications to these courses must include well defined tutor training programs to develop their teaching skills – especially methods to promote interactive learning and hence broaden student participation. A further improvement could be to extend the time for tutorial sessions to 90 minutes but this would require major restructuring of the overall curriculum.

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