Active Learning in the Third Year Statistical Physics Module at the University of the Witwatersrand

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Abstract. Active learning techniques were used for the first time in the Statistical Physics module presented to third year students at the University of the Witwatersrand in the first semester of 2009. The reaction of the students, recorded in a formal Student Assessment of Lecturer Performance, administered by the Centre for Teaching and Learning Development at the University, was overwhelmingly positive. In addition, the final results of the students were excellent. This paper reports on the methods employed, the results of the student survey and the module results. These results are compared with the results of the same group of students in the second year Thermal Physics module, taught by the same lecturer using more traditional methods of instruction, during the second semester of 2008. The employment of innovative teaching strategies makes a significant difference to the confidence and attitude of the students, and an increase in the level of performance of the majority of students is apparent. Active learning is now the standard method of instruction in both the second and third year Thermal and Statistical Physics modules, and details of the materials developed over the last three years will be provided.

1. Introduction

A recent review of the research into Active Learning techniques [1] examines the evidence for the effectiveness of active learning. Four types of active learning are identified, these being active learning, collaborative learning, cooperative learning and problem-based learning. In essence, the types of teaching interventions that fall under the heading of active learning involve changing the approach of the lecturer from the traditional model, where a lecturer imparts knowledge and the students in the lecture absorb the information. The introduction of active learning techniques have, in the past, lead to a number of beneficial outcomes. Prince quotes several studies which claim improved student attitudes, an improvement in skills development and retention of knowledge. He also cautions that empirical evidence of improvement in student performance may be less convincing than expected. Prince also points out that the adoption of active learning within a discipline is often treated with scepticism by those teachers within the discipline who regard changing the approach to teaching as following fashionable educational trends, and not based on hard empirical evidence.

Felder *et al* [2] make a stronger case for the for the adoption of teaching methods that they, and the works that they cite, believe facilitate learning. These include the publication of clear instructional objectives for each course, establishing of the relevance of course material, balancing concrete and abstract information, promoting active learning, using co-operative learning, giving challenging but fair tests and examinations and conveying concern about the students' learning.

They also point out that the techniques thatthey are proposing can be implemented without large investments in infrastructure (such as computers). This has a particular resonance in South Africa.

There have been many studies of active learning teachniques applied to large first year undergraduate classes in Physics and Engineering (see for example the review by Thacker [3]). It has been less common to find these techniques used in upper level Physics [4]. This is perhaps related to the fact that these classes are usually much smaller than first year classes, and that the courses will often be taught by senior staff who may be more inclined to use methods that they have found effective during the course of long careers.

This paper reports on an attempt to introduce active learning techniques in the third year Statistical Physics at the University of the Witwatersrand (WITS) during 2009. It will be shown empirically that the introduction of active learning has a profound effect on student attitudes and motivation, and that the results of the students in the module improved when compared to their results in the Thermal Physics module presented in the previous semester (at the end of 2008). Active learning methods are now utilized in both of these modules, and the methods adopted continue to play a positive role in facilitating effective learning.

2. Teaching Strategies

The teaching strategies employed in the first instance were inspired by a workshop given by Richard Felder at WITS in December 2008. I had, over the years, attempted to bring a more interactive approach to lecturing, and met with some success. As Table 1 in the next section shows, the students in the second year Thermal Physics module recognized my intention, but obviously did not feel comfortable in becoming actively involved in the lecture. Despite asking the obvious 'Any questions?' at the end of each lecture example, derivation and lecture I experienced very little feedback. There was also an obvious drop in student attention during the course of each 45 minute lecture. The methods described by Felder in the workshop, and in his publications offered the possibility of improving communication with students in demanding upper level courses. I introduced active learning explicitly during the first lecture of 2009, so the students were fully aware that they were a test group. It should be noted that the module curriculum was not altered significantly from the Statistical Physics module presented in 2008.

2.1. Lecture Activities and Co-operative Learning

Felder *et al* [5] point out that different students have different learning styles, and that many students have problems dealing with abstract information. Moreover, it is clear [1] that the attention of students in a lecture drifts away from the lecture material after approximately 20 minutes. Lecture activities allow the lecturer to break the monotony by introducing a set activity. These activities varied. Sometimes they were applications of material presented in the previous lecture. Other activities included the derivations of some of the fuundamental equations, and yet others were used to acquaint the students with new material (e.g. adiabatic demagnetization). Students were encouraged (but not forced) to discuss the material with their neighbour in the lecture theatre, thus promoting co-operative learning. After a suitable period of time (depending on the complexity of the activity) we discussed the solution to the problem. The class were told that they were responsible for providing a clear solution to the activities, and that these activities would form the basis for test and exam questions.

2.2. Minute paper and responses

Minute papers (see Felder *et al* [2]) were administered at least once a week (usually after the end of the only double lecture). The students were asked to anonymously write down the most important points made in the double lecture, and the least clear point(s) on a pro forma handout. Before the next class I prepared a table showing the frequency of reponses to both questions, and commented on the students' identification of the most important points. It was gratifying to note that the majority of students were proficient at recognizing the most important points. I responded to each of the 'unclear' points at the start of the next lecture, whether it was a verbal comment or part of a prepared set of display slides. Often these responses gave me the opportunity to present an alternative representation of the material associated with the 'unclear' points. As Table 1 shows, the students appreciated that I took these minute papers seriously. The minute paper responses were posted on the internet following the lecture in which they were presented, and they proved to be a valuable revision resource, according to the students.

2.3. Conceptual Questions

Both Thermal Physics and Statistical Physics offer the opportunity to probe the students' understanding of difficult concepts (e.g. entropy, adiabatic processes). During lectures I would invite students to discuss conceptual questions in pairs. This often elicited some lively debate.

2.4. Active tutorials

The students were encouraged to prepare for tutorial sessions by attempting all of the set problems on the tutorial sheet. Volunteers were called for to present solutions on the board, and if no-one volunteered than a student was selected by the lecturer. This allowed the students the opportunity to see how their colleagues solved a particular problem, and there was generally more discussion compared to when I presented the solution and asked for comments and questions, as I had in previous years.

3. Effect on Active Learning Strategies on the students

Assessment of the success of the measures described in the previous section were two-fold. Firstly, I employed the service offered by the Centre for Teaching and Learning Development (CLTD) at WITS and administered two formal Student Surveys of Lecturer Performance (SELP) surveys. The first of these was, at the time, purely for promotional and teaching development purposes. The subject of this survey was my teaching of the second year Thermal Physics module in the second semester of 2008. Following the introduction of active learning to the third year Statistical Physics module in 2009 I ran another survey with exactly the same format, and I also asked the students to comment explicity on the introduction of the new teaching style.

3.1. Comparison of Student Evaluations

SELP at the CLTD follow a format that will be familiar to many involved in education research. A positive assertion of lecturer performance is made, and the students indicate whether they (A) strongly agree, (B) agree, (C) are neutral, (D) disagree or (E) strongly disagree. Each individual response is scored as follows: (A) 10, (B) 7.5, (C) 5, (D) 2.5 and (E) 0, and an average is then obtained for each item from all responses. A SELP is voluntary, but these must be presented by those seeking confirmation or promotion at WITS. The efficacy of SELP surveys is often challenged by university teachers, as described by Felder [6]. He points out that this is often done without providing any evidence that they are not effective. The results of SELP surveys can be used to improve and refine teaching practice, and the results of such surveys are likely to be significant. Complementary initiatives, such as peer reviews, will strengthen their effectiveness.

The results of pre- and post-intervention SELP on essentially the same cohort of students are tabulated in Table 1. The overall results show a positive response to active learning. Several items have been highlighted in *italics* (average score decreases from 2008 to 2009) and in **bold**. The bold items indicate results that I regard as particularly significant. Perhaps the most significant is the large relative increase in the number of students who felt more comfortable in participating in the class (although there was a small decrease in the score for the item 'Encourages audience participation'). Active learning appears to have had the effect of improving the students' attitude to several items considered to be positive for effective learning. The results also show an appreciation of the extra work involved in treating the feedback from the students with the respect it deserves ('Gets feedback on understanding') and in establishing the relevance of the course material ('Digressions made which add interest' and 'Links lecture to other parts of the course').

Table 1. The results of two SELP administered by the WITS CLTD during the modules presented in 2008 and 2009. The student samples are for second and third year Physics modules on related material, taught by the same lecturer, before and after the introduction of active learning techniques. The highlighted items in the table are discussed in the text.

Abbreviated Assertion	2008	2009	% Change
Makes clear the purpose of the lecture	8.96	9.29	+ 3.7
Stimulates interest in the subject	**8.08**	**9.11**	**+ 12.7**
Always well prepared for class	**9.24**	**10.00**	**+ 8.2**
Available for consultation outside lectures	8.66	9.29	+ 7.3
Encourages audience participation	*9.43*	*9.29*	*- 1.5*
Communicates effectively	8.47	8.93	+ 0.46
Chooses and organizes material well	8.08	8.93	+ 10.5
Pitches lectures at the appropriate level	8.66	9.11	+ 5.2
I gained understanding of concepts	7.70	8.58	+ 11.4
Motivated to read/do extra work	7.70	8.04	+ 4.4
Shows thorough subject knowledge	9.24	9.47	+ 2.5
Clear, understandable explanations	**8.08**	**9.11**	**+ 12.7**
Grasp of my level of knowledge is realistic	8.08	8.40	+ 4.0
Gets feedback on understanding	**7.70**	**9.65**	**+ 25.3**
Summarizes main points effectively	8.08	8.93	+ 10.5
Writes legibly on the board	*9.24*	*8.93*	*- 3.7*
Links lecture to other parts of the course	**7.89**	**9.47**	**+ 20.0**
Digressions made which add interest	**7.89**	**9.47**	**+ 20.0**
Directives for written work clear	8.47	9.29	+ 9.7
Lecturer has enthusiasm for subject	8.85	9.83	+ 11.1
Approachable for questions	**8.96**	**9.29**	**+ 13.9**
Welcomes different viewpoints	8.08	8.93	+ 10.5
Comfortable about participating	**6.54**	**8.58**	**+ 31.2**
Average	**8.33**	**9.44**	**+ 9.8**

The comments made by the students in the open-ended questions in the second survey, in which they were particularly asked to give their opinion of active learning, were overwhelmingly positive. All students who responded expressed an appreciation for the fact that they were engaged, rather than passive, during lectures and tutorials.

3.2. Comparison of Module Results

There were a total of fourteen students who took both the Thermal Physics module at the end of 2008 and the Statistical Physics module at the beginning of 2009. The final and examination results for these 'common' students are tabulated in Table 2. With two notable exceptions, the performance of the students has either improved or remained roughly the same following the introduction of active learning. More than 60 % of students improved both their final and examination mark. A comparison of the examination results for 2008 and 2009 also show an improvement (see Table 3) and this improvement is mirrored in the final marks which shows a similar relative improvement. One might expect third year students to perform better than second year students overall, but it should be noted that the results in the other third year year modules were not uniformly excellent during 2009. It is true that the student numbers are small, and so the improvements in performance noted may be statistical fluctuations, it can nevertheless be confidently concluded that active learning techniques do not have a negative effect on the results.

Table 2. Comparison of student performance in 2008 and 2009 for students who took both modules in successive years.

Change in final result	Total mark	Examination mark
+ 20 % to + 30 %	2 (14 %)	2 (14 %)
+ 10 % to + 20 %	3 (21 %)	3 (21 %)
0 % to + 10 %	4 (29 %)	5 (36 %)
- 10 % to 0 %	3 (21 %)	2 (14 %)
- 10 % to - 20 %	1 (7 %)	1 (14 %)
- 20 % to - 30 %	1 (7 %)	1 (14 %)
Improved mark	9 (64 %)	10 (71 %)

Table 3. Comparison of final examination results in 2008 and 2008 for the full complement of students in each year.

	2008	2009
Class average	70.8 %	76.0 %
Pass Rate	89 %	100 %

4. Conclusions

Active learning techniques were introduced in the third year Statistical Physics module offered in the School of Physics at WITS during the first semester of 2009. A comparison of SELP and final module results for largely the same group of students support the conclusion that the intervention has been successful. The students who attended the third year module presented using active learning initiatives described in this paper not only showed a general improvement in their final results, they also appear to be happier and more confident than they were when more traditional methods were employed.

References

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