Improving Teaching of a University Module — Application of Action Learning Methodology

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Abstract

The *motivation* for the present project has come from the realisation of the apparent difficulties in teaching the module *Quantum and Solid State Physics* [QSSP] taught within the course BSC (Hons) Applied Physics, Year 2 FT and Year 3 PT mode. This module can be briefly characterised as follows: (1) one of the most difficult modules; (2) a high amount of new and non-classical concepts; (3) serves as the foundation for other final year courses; and (4) poor examination results 1992/93 and 1993/94 (PT).

The *aims* of the project are as follows: (1) educational research into teaching a physics module; (2) application of the Action Learning Methodology; (3) development of novel teaching methods; and (4) improve teaching of QSSP.

The *methods and tools* worked out to improve the teaching in the module QSSP are three-fold, namely: (1) Analysis of Examination Results 1993-94 and 1995; (2) Modifications Introduced to Teaching, which concerned: module content, structure of the revised lecture notes and teaching methods; (3) Tools for Evaluation of the Teaching Modifications, which comprised two questionnaires, each dealing with the following aspects:

Questionnaire 1: (1) major topics difficulty, presentation, lecture notes and importance; (2) comparison of old and new lecture notes; and (3) level of difficulty for sub-topics.

Questionnaire 2: (1) opinions on teaching; (2) preference on type of transparencies; (3) preference on type of lecture notes; (4) workload of the course; (5) mid-term test; (6) new lecture notes; (7) suggestions for modifications to the Teaching; (8) reflection on students' own study; and (9) difficulties in study.

The *tangible outcomes* of the project can be divided into two groups, namely, (1) the outcomes specific for the module in question, i.e., deep changes in the module QSSP content and teaching methods, the revised lecture notes (MS Word + diagrams), the computer multimedia packages for visualization; and (2) the general outcomes which can be utilized in improving teaching of any module, i.e. the method of identification of teaching difficulties and the tools for evaluation of the teaching modifications.

A brief summary of the overall results and outcomes of this project has been presented at the Action Learning Project Conference (see, *Programme and Abstracts*, The Hong Kong Polytechnic University, November 1996), whereas a full presentation is provided in two detailed research reports. In the first report (Rudowicz and Wu, 1996), the methods and tools listed above are dealt with. In the second report (Rudowicz, Tsoi and Lau, 1996), the development of the computer multimedia packages for visualisation of complicated problems for some lectures in the module QSSP (Semester B) is dealt with. One of the objectives of the Action Learning Project, which comprises about 50 individual projects, the present one being one of them, has been to share the experiences with other academics. Hence in this paper we provide a general overview of the ideas, techniques and tools which may be helpful in improving teaching in other modules. It is hoped that the present paper may be useful not only for physics or science subject teachers but for all tertiary education teachers.

Introduction

In order to improve teaching of the module Quantum and Solid State Physics (QSSP) taught within the course BSC (Hons) Applied Physics, Year 2 FT and Year 3 PT mode, the present project has combined two important aspects:

1 educational research into teaching a specific physics module based on the Action Learning Methodology (e.g. Kember, 1994; Kember et al., 1994; Kember and Kelly, 1994) and utilising the results of the extensive local educational research (e.g., Balla et al., 1991; Biggs, 1993; Stokes et al., 1989)

2 development of novel teaching methods incorporating the acquired knowledge of the specific factors, which bear on the quality of teaching.

In our case the data have been obtained within one particular module, taking into account the ramifications and interrelationships with other science modules. Hence, the extensive analysis of these particular data may help to achieve a proper understanding of the mechanisms responsible for improving quality teaching and learning within other science modules. Therefore, the experience gained in the course of this project may form a basis for future positive changes in other university modules, especially science modules.

The work dealt with in this paper concentrated on the three following areas:

Area 1: The analysis of exam results in the academic year 1993/94 and 1994/95 and the correlative survey of the examination papers as well as the analysis of the Teaching Evaluation and Improvement Package (TEIP) results for the past years have been carried out. This has enabled identification of (1) the major teaching problems encountered by students; (2) the concepts which present special difficulties in understanding and/or memorisation for students; (3) the most common misconceptions and their correlation with the alternative structures of the exam questions; and (4) the poor associative links between different parts of the module QSSP and other related AP modules. The method and results are summarised later in this paper.

Area 2. The results of the first phase have been taken into account as much as possible in the second phase of the project. Consequently some changes to the syllabus of the module QSSP have been proposed. The old hand–written lecture notes and transparencies for the module QSSP (Semester B) have been modified accordingly with regard to the content, layout and presentation. The revised version has been worked out with great effort using MS WORD 7. The modifications to teaching suggested by the analysis (area 1) and by data collected using other ways as well as their implementation regarding the module content, revised lecture notes and teaching methods are described in Chapter 3.

Area 3. The last phase of the project dealt with (1) the evaluation of teaching in the module QSSP in Semester B of 1995/96, when the modified lecture notes and transparencies were used for the first time; and (2) a comparative analysis of students' opinions on the old (lecture 7, 8 and 13) and new (lecture 1-6 and 9-12) teaching materials. Data were collected by two sets of self-administered questionnaires from 62 students, which included 26 full-time (FT) and 36 part-time (PT). Results showed that the overall quality of teaching was quite effective in relation to the clarity and quality of presentation during lectures as well as the usefulness of teaching materials, especially for the new ones. A passive study attitude of students was also revealed from their suggestions for modification of teaching with regard to their self-reflection on their study. The tools for evaluation of the teaching modifications are presented as well as an overview of the main education research results are presented in later sections of this paper.

Analysis of the Exam Results for the Module QSSP (Semester B)

The suggestions for improvement of the teaching materials, module content and teaching methods have been collected by various means. The major source of the detailed suggestions about specific aspects has been provided by the analysis of the exam results in the academic year 1993/94 and 1994/95 and the correlative survey of the examination papers which has been carried out in summer 1995 and Semester A of 1995/96. An analysis of the TEIP results for the past years and the students' comments gathered in private interviews at the end of the Semester B have also provided useful suggestions for improvements. Since this analysis is discipline-specific, here we only summarise the main points, whereas the full description of the method can be found in the report (Rudowicz and Wu, 1996).

The procedure for the analysis was as follows. First the source lecture and the sub-topic were identified using the current syllabus for the module QSSP (Semester B). At that stage the sub-topics were named explicitly by appropriate meaningful abbreviations. At a later stage when the Questionnaire 1 (see Chapter 4 and 5) was finally devised the subtopics for each lecture/week were coded in a consequtive way by the question numbers from Q53 to Q118. This coding system was used for the final tabulation of the statistical data and their presentation. Second, the marks for each exam question (EQ) were extracted from the scripts and the number of students, who either did not attempt to answer a given exam question at all or in a few cases obtained a mark of zero, were recorded. Subsequently appropriate average and percentage quantities were calculated. Third, the content of student answers for the questions, which revealed low student performance, have been analysed in order to identify possible sources of problems. The results of the statistical and content analysis are presented in full in the report (Rudowicz and Wu, 1996).

In summary, the comprehensive analysis of the exam results has enabled identification of (1) the major teaching problems encountered by students; (2) the concepts which present special difficulties in understanding and/or memorisation for students; (3) the most common misconceptions and their correlation with the alternative structures of the exam questions; and (4) the poor associative links between different parts of the module QSSP as well as to a certain extent between the module QSSP and other related AP modules. This method can be used for other university modules for which structured examination questions are adopted. Hence, the method of locating the weak points in the teaching and learning process via a deeper analysis of examination results is of general applicability.

Modifications Introduced to Teaching the Module QSSP (Semester B)

In order to remedy the perceived problems identified above, some modifications have been introduced into teaching the module QSSP/Semester B, which can be categorised into three major sub-areas as described below.

Module Content

In the past few years students have indicated in private converstaion their concern regarding the large quantity of material in the lecture notes as well as the tutorials and assignments. Some student groups have also commented about 'too difficult layout of the lecture notes' and that a 'summary of main points and plan of lecture would be useful'. Therefore, the overall content of some longer lectures has been reduced by selecting certain parts which can be regarded as optional. These parts where specially marked and were either briefly discussed at lectures (in the FT mode) or were left to be read by interested students (in the PT mode). Thereby more time could be devoted for deeper discussions of more essential topics. The changes introduced to the module

content are specific only for this module and do not apply to the general reader. A full list of these changes can be found in (Rudowicz and Wu, 1996).

One modification, which bears on the students' motivation to learn the subject, may be useful for other lecturers. In Lecture 1, the previous extended introduction aimed at presenting the field of Solid State Physics in perspective has been reconsidered. Several diagrams summarising different sub-areas, potential applications and experimental techniques were used, which were found to be of little use for students at that stage. It was replaced by a two-page introduction to the module (see Appendix 2 in Rudowicz and Wu, 1996).

A more coherent 'pedagogical approach' has been implemented throughout the lectures. It begins with a clear description of a physical problem, followed by structured mathematical derivations of equations for a given physical model, analysis of special cases (whenever applicable) and a graphical presentation of physical results. More effort has been put into finding applications from 'real life' to illustrate the results of a given physical model.

Special attention was given to revise sections identified as posing major difficulties in understanding and / or memorisation for students. Logical flow of explanations, clarity of derivations of subsequent steps in the development of the related concepts as well as the selections of diagrams used for illustration of the results have been improved.

Structure of the Old and Revised Lecture Notes

The old version of the transparencies were handwritten, whereas diagrams were presented on separate pages for the convenience of copying from textbooks (see Appendix 3 in Rudowicz and Donna, 1996 for sample pages). An advantage of the handwritten transparencies was the use of colours to emphasise various points. However, the text was not satisfactorly clear in places due to comments introduced at later stages of development. The text flow was not continuous because the relevant diagrams appeared in the copied version of the lecture notes one or two pages later. In the past few years, students have also complained that the sequence of the pages in their handout copies had been sometimes wrong due to mixing of pages during photocopying. They have indicated strong preferences for typewritten notes. Other students' comments were about the numbering of equations and providing the SI unit form for all equations. In order to introduce substantial changes to the content, text organisation and the set of diagrams, it was necessary to use an advanced word processor. The development of the new version of the lecture notes (in MS Word 6.0) was made in three stages as described in Rudowicz and Wu (1996).

Independently the newly selected diagrams for illustration have been scanned into the picture files. The final stage of development of the new version was completed by the lecturer. It comprised the further improvements to the text, logic and presentation, taking into account the problems identified for a given lecture / topic as discussed above. The technical aspects, namely, layout, pagination, inserting each picture file into proper place in text as well as final corrections to symbols, text and tables were also completed at this stage. Sample pages of the revised lecture notes are included in the Appendix 3 in Rudowicz and Wu (1996).

The structure of the transparencies was devised in such a way that they could be used directly as handouts. The rationale behind this option was twofold. Since the command of English of our students is generally poor, too many spoken lectures with only the major point presented on transparencies seemed to be detrimental for the learning process. Therefore, basic written descriptions and proper explanations were included on the transparencies. The underlying idea was to reduce the amount of lengthy and complicated sentences and whenever possible to replace them by concise, simple ones as well as to increase a 'pictorial / symbolic' way of explanation by the way of an equation or a diagram. On the other hand, in this way no extra handout version needed to be prepared. Thus another time consuming task could be avoided. It appears that students

strongly prefered this structure of combined transparencies / lecture notes, which will be discussed in more detail later in this paper.

The structural changes introduced into the lecture notes may be of interest to other lecturers. These included:

1 adding a plan of each lecture at the beginning;

2 adding references to most relevant books and chapters, which were used for preparation of a given lecture;

3 placing diagrams within the pertinent text by inserting the scanned picture files in proper places;

4 adding a summary of each lecture at the end in form of revision questions devised in such a way that answers can be found directly within the lecture notes. Care has been taken to reformulate the text in such a way that the answers to the revision questions are easy to find;

5 layout of derivations of equations was revised to show clearly:

- the outline of a physical problem and assumptions
- mathematical tools / equations / identities required
- steps in the derivations
- final solution / results.

All major equations have now been numbered in a consecutive way.

6 scaling up the amount of 'doing', while scaling back the 'watching' — by omitting full explanations for some topics, more time could be spent on letting students go by themselves through various steps of derivations;

7 better correlation between the content of the lecture notes and the tutorial problems as well as the revision questions have been attempted in order to eliminate students' complaints that they sometimes cannot deduce the answers from the lecture notes;

8 new ideas / concepts / notions were emphasised when they appeared for the first time by larger fonts in text and repeated explanations during lectures. This was to satisfy students' comments that they learn more during lectures in this way and that this facilitates revisions of lecture notes.

9 more attention was put into problem solving skills, especially those regarding the analysis of a physical model, its consequences and derivation of final equations (see also the item 6 above).

Teaching Methods

Starting from 1994 / 95, a different teaching pattern for the FT and PT students has been introduced, namely, a two hour lecture and one hour tutorial and a two hour lecture including a 20-minute tutorial, respectively. However, the content and teaching methods were kept as close as possible for both groups of students. The major innovation to teaching methods, prompted by comments from former students, was the introduction of short quizzes at each lecture. Two questions for which short answers can be given within 5-10 minutes were prepared for each lecture. The quiz number and questions were typed in large fonts to fill a page and copied onto a transparency. Students were given answer sheets, while the questions were only shown on the overhead projector. The quizzes were administered after the break at the beginning of the second half of the following lecture. The aim was to motivate students to learn not only at the end of the semester, while preparing for the final exam (as it is a common pattern), but from lecture to lecture. Assessment was done the same week and marked answer sheets were distributed at the beginning

of the break. If time allowed, a short discussion of results of the previous quiz was carried out. Students were also informed that the quiz marks will be taken into account in exam marks.

Since the quizzes provided an efficient method for continuous assessment, the number of written assignments was reduced from six to four. The workload for each assignment was also reduced. This was also motivated by the past students comments. Hints for solutions of some more difficult tutorial questions were provided. The new format of tutorials comprised two sections, namely the revision questions (attached at the end of the lecture notes), which were discussed in the first part of a tutorial session, and the tutorial problems, which were supposed to be solved by students at home and discussed in detail at class. In practice only a few best students attempted solving the problems at home. Therefore not all questions could be solved at class because of lack of time. Only selected tutorial questions have been solved and discussed in detail in class. In some cases model solutions for important questions were provided for students to pursue at home.

No mid-term test was implemented this year, unlike in the previous few years, because it would be too much work for students as well as the lecturer in view of continuous quizzes.

The general attitude of the lecturer was oriented towards encouraging students to read lecture notes and relevant textbooks, to study hard and make conscientious efforts in their study. Following the suggestions of former students, an image formation exercise were carried out to improve the image of the subject perceived as the most difficult one. This attitude is reflected in the Introduction to the module (see Appendix 2 in Rudowicz and Wu, 1996). This has been motivated by remarks of some students. A characteristic opinion of one current year 3 student reads as follows (exact quotation):

> Since I had heard of some bad voice to this subject from year 3 students before I have learnt this subject, I was afraid of this subject at the beginning. However, I do not agree with them now and do feel interest in this subject. Therefore, try to improve the image of this subject, e.g., remind us not to say bad effect of this subject next year.

Finally, it is worthwhile to emphasise that our experience with encouraging former students to make comments reveals (1) the usefulness of student participation in shaping some aspects of the teaching process and (2) the importance of student motivation for successful teaching.

Tools for Evaluation of the Teaching Modifications

In order to obtain insight into the students' perception of the modifications introduced to teaching the module QSSP (discussed above), a set of two questionnaires was devised during March / April 1996 (for details see, Rudowicz and Wu, 1996). It was then realised that the same group of students must be exposed to both the 'old' and 'new' teaching. Hence lectures 1-6 and 9-12 have been delivered in the new format, whereas for comparison lectures 7, 8 and 13 were given using old transparencies. Major modifications were explained to students during lectures and tutorials.

A pilot study on five students each from the FT and PT mode have been carried out to check student understanding of the questions and the time needed to fill in the questionnaires. After fine-tuning, the two questionnaires were administered to FT students (two groups combined) at the last tutorials, whereas at the last lecture (week 14) to PT students. The raw data were processed by the Action Learning Project (ALP) staff and supplied on a diskette. The analysis of these data were carried out using the SPSS software package. The results will be presented in the next section of this paper.

Questionnaire 1 was aimed at surveying student opinion on individual topics taught within QSSP / semester B. In Part I major topics — i.e., titles for each lecture — are listed and for each lecture four areas are surveyed, namely, (1) level of difficulty; (2) clarity of presentation; (3) quality

of presentation of lecture notes; and (4) importance of the topic. Part II contains a detailed list of topics actually covered within each lecture. This list corresponds to a great extent to the section headings within a given lecture, in some cases simplified to encompass two closely related topics. Students were requested to identify only the topics that were exceptionally difficult for them.

Questionnaire 2 surveyed the five areas, namely, (1) opinions on the teaching; (2) new lecture notes (the MS Word version); (3) suggestions for modifications to the teaching; (4) reflection on your own study; and (5) difficulties in your study. Appropriate scales have been devised for each area.

The original questionnaires can be found in Appendix 4 in Rudowicz and Wu (1996). The structure of the questionnaires can be used for evaluation as well as, to a certain extent probing the weak and strong aspects of current teaching and / or teaching modifications in any university module. Application of the questionnaires, which is envisaged to be carried out at the end of a given course, may help further improve teaching in the next academic year (for details see Rudowicz and Wu, 1996). We would appreciate if readers intending any future usage and / or adaptation of the questionnaires would notify us in writing to obtain copyright permission.

Results and Discussion

Questionnaire 1 (QT1)

Major Topics: Difficulty, Presentation, Lecture Notes and Importance

This part of QT1 aims at obtaining the means and standard deviations of the lectures' difficulty, presentation, lecture notes and importance for both FT and PT students. The lectures were identified by their titles, i.e., the major topics. The analysis of data on the highest and lowest scores in the four categories (a) – (d) for a given lecture / topic enables identification of general problems with some lecturers as well as of any significant differences between FT and PT students. Detailed analysis is presented in Rudowicz and Wu (1996). Table 1 is provided for illustration. A five point scale (5,4,3,2,1) is used, with 5 meaning the highest level (see the table below).

Table 1: Means and standard deviations of major topics' difficulty, presentation, lecture notes and importance for both FT and PT students

	5	4	3	2	1
1. Level of Difficulty	Very Difficult	Difficult	Quite Difficult	Easy	Very Easy
2. Clarity of Presentation during the lectures	Very Clear	Clear	Quite Clear	Confusing	Very Confusing
3. Quality of Presentation of the lecture notes	Excellent	Good	Quite Good	Poor	Very Poor
4. Importance of the topic	Very Important	Important	Quite Important	Useless	Totally Useless

MAJOR TOPICS	(a) Level of Difficulty (N=62)		(b) Clarity of Presentation (N=62)		(c) Quality of Presentation of Lecture Notes (N=62)		(d) Importance of the Topic (N=62)	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
1. Lattice Dynamics	3.3	0.9	3.5	0.8	3.5	0.8	3.6	0.8
2. Thermal Properties of Solids I Specific Heat (C_V) Theories	3.5	0.8	3.4	0.8	3.5	0.8	3.7	0.7
3. Thermal Properties of Solids II Thermal Expansion.	3.6	0.7	3.4	0.7	3.5	0.6	3.5	0.8
4. Thermal Conductivity and Thermoelectricity	3.8	0.8	3.4	0.8	3.5	0.8	3.7	0.8
5. Interaction of Phonons with X-Rays, Neutrons and Light	3.9	0.7	3.3	0.7	3.3	0.8	3.7	0.8
6. Superconductivity I	3.7	0.8	3.5	0.8	3.4	0.9	4.1	0.9
7. Superconductivity II*	4.0	0.7	3.5	0.8	3.1	1.0	3.9	0.8
8. Magnetism - introduction*	3.6	0.9	3.3	0.9	3.3	0.9	3.7	0.8
9. Diamagnetism and Paramagnetism	4.0	1.0	3.3	0.8	3.3	0.8	3.9	0.8
10. Ferromagnetism	4.1	0.8	3.4	0.8	3.3	0.8	3.8	0.8
11. Antiferromagnetism and Ferrimagnetism	4.2	0.8	3.4	0.9	3.4	0.8	3.8	0.8
12. Applications of Magnetic Materials	3.7	0.9	3.5	0.9	3.5	0.8	3.6	0.9
13. Magnetic Resonances*	4.4	0.8	3.2	0.9	3.3	0.8	3.7	0.8
Total Average M/SD	3.8	0.5	3.4	0.6	3.4	0.5	3.7	0.5

The asterisk * indicates the lectures for which the old lecture notes and transparencies were used.

The data indicated that both FT and PT students considered the lectures as difficult. The clarity of presentation during lectures as well as the quality of the presentation of lecture notes were considered as between 'clear' and 'quite clear', whereas the major topics were overall considered as important.

Comparison of Old and New Lecture Notes

For the comparison of old and new lecture notes, Table 2 presents the means, standard deviations and level of significance for both FT and PT students. Paired t-test was performed on these data. Statistically analysis (Rudowicz and Wu, 1996) of any significant differences, in our case between new (Topics 1-6, 9-12) and old (Topics 7, 8, 13) lecture notes, enables, in general, to differentiate between various sections of the teaching and / or teaching materials with respect to the four categories studied.

Table 2: Means, standard deviations and level of significance of old and new lecture notes for both FT and PT students

LECTURE NOTES	(a) Level of Difficulty (N=62)		(b) Clarity of Presentation (N=62)		(c) Quality of Presentation of Lecture Notes (N=62)		(d) Importance of the Topic (N=62)	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
New (Topics 1-6, 9-12)	3.8	0.5	3.4	0.6	3.4	0.6	3.7	0.5
Old (Topics 7,8,13)	4.0	0.5	3.3	0.7	3.2	0.7	3.8	0.5
Level of Significance	*t* = 3.60 *df* = 52 *2-tail sig*=0.001		*t* = 2.07 *df* = 59 *2-tail sig*= 0.043		*t* = -2.41 *df* = 57 *2-tail sig* = 0.019		*t* = 0.95 *df* = 57 *2-tail sig* =0.348	

Our data indicate that both FT and PT students perceived the old lecture notes as more difficult than the new ones regarding reading the notes and learning from them. New lecture notes were perceived as more clear and their quality of presentation was considered better. All topics, however, were perceived as equally important in the case of both the old and new lecture notes. This indicates that while the students accept the content of the lectures regardless of its form, they appreciate the effort put into reusing and restructuring the lecture notes (see Table 4).

Level of Difficulty for Sub-Topics

This part of QT1 aims at examining if there is a difference between student and lecturer perception of the level of difficulty for each sub-topic within each week's lecture. The level of difficulty for each sub-topic / week was ranked by the students and the lecturer separately. For illustration partial data are shown in Table 3. A five point scale (5,4,3,2,1) was used, with '5' meaning the most difficult and '1' the easiest. For easy reference, the question numbers as used in Questionnaire 2 / Part II have been added next to each sub-topic within each week's lecture.

Table 3: Level of difficulty for sub-topics (Lecture 1, 6 and 7 only)

WK	Sub-Topics	% of Students (FT & PT N=62)	Students' Ranking	Lecturer's Ranking
1	i Q53	4.8	1	1
	ii Q54	17.7	2	2
*	iii Q55	35.5	3	4
*	iv Q56	37.1	4	3
6 *	i Q75	17.7	4	1
	ii Q76	11.3	2/3	3
*	iii Q77	25.8	7/8	4
*	iv Q78	11.3	2/3	5
*	v Q79	9.7	1	2
*	vi Q80	22.6	5	7
	vii Q81	24.2	6	6
	viii Q82	25.8	7/8	8
	ix Q83	51.6	9	9
7	I Q84	12.9	1	1
	ii Q85	30.6	3	3
	iii Q86	32.3	4	4
	iv Q87	24.2	2	2
	v Q88	48.4	5	5
	vi Q89	50.0	6	6
	vii Q90	54.8	7	7

The asterisk * indicates a difference between the students and the lecturer in ranking the difficulty for that sub-topic.

This analysis may indicate whether there are any significant differences between students and lecturers in ranking the level of difficulty for some sub-topics. Detailed results are discussed in Rudowicz and Wu (1996). It is worthwhile to note that the greatest difference was found in the week six lecture in which the students and lecturer perceived different levels of difficulty for most of the sub-topics. Some were perceived as more difficult for the students while easier for the lecturer and vice versa. However, there were also five lectures, in which all sub-topics were perceived with the same level of difficulty for both the students and the lecturer. This might imply that the lecturer did not appreciate the students' strengths and weaknesses in learning sub-topics within this module. Some aspects of the module might have required higher learning capabilities

for the students than those assumed by the lecturer, whereas lower in others. A discrepancy between the lecturer's expectations towards students and their actual capabilities might affect the quality of teaching. These findings will be taken into account in further revisions of the lecture notes and teaching methods. Hence such analysis may also help to provide ways of improving teaching.

Questionnaire 2 (QT2)

Opinions on Teaching

This part of QT2 investigates student opinion of different components and aspects of teaching and learning as well as teaching materials, which were measured by the 14 items stated in Table 4. The highest and lowest mean scores may indicate particular opinions among students. Statistical differences between the opinions of FT and PT student on teaching were also studied. A five point scale (5,4,3,2,1) is used, with 5 meaning the highest level (see the table below).

Table 4: Means and standard deviations for Q.1-14 — Opinions on the teaching

Q.	ITEM	FT (N=26)		PT (N=36)		TOTAL	
		M	SD	M	SD	M	SD
1	Lecturer's Explanations in Lectures	3.8	0.8	3.5	0.9	3.6	0.8
2	Lecture Notes	4.1	0.8	4.3	0.7	4.2	0.7
3	Short Quizzes	3.8	0.8	3.5	0.8	3.6	0.8
4	Revision Questions	3.9	0.6	3.9	0.7	3.9	0.7
5	Tutorial Questions	3.8	0.6	3.9	0.7	3.8	0.6
6	Tutorials	3.9	0.8	3.7	0.9	3.8	0.8
7	Assignments	3.7	0.6	3.6	0.5	3.7	0.5
8	Textbooks	3.1	1.1	3.4	1.1	3.3	1.1
9	Own Additional Reading	3.0	0.8	3.5	1.0	3.3	1.0
*10	Discussions with Fellow Students	3.8	0.9	3.3	0.9	3.5	0.9
*11	Discussions with the Lecturer / Tutor	3.8	0.7	3.4	0.7	3.6	0.7
12	Lecturer's Explanations	4.0	0.8	3.6	1.0	3.8	0.9
13	Reading from Transparencies	3.2	0.8	3.5	0.8	3.4	0.8
14	Reading from Own Copy of Lecture Notes	3.9	0.6	3.8	0.8	3.9	0.7

* with statistically significant difference between FT/PT students

For example, our data revealed that both FT and PT students considered most of the components and aspects of teaching to be useful as well as teaching materials used. The most useful way of learning was reading lecture notes, while the least useful ways were reading textbooks and doing additional reading. This might be interpreted as students finding the studying materials obtained from the lecturer as more substantial and useful than those found by self-seeking methods. The

reasons may be two-fold. On the one hand, the students may have lacked ability to access those other useful study materials. On the other hand, this finding may reflect the students' passive attitudes towards their own study. They preferred to acquire knowledge from teachers directly rather than actively putting time and effort into seeking knowledge themselves. For the PT students, discussions with fellow students and the lecturer (who was also the tutor) were regarded as less useful when compared with responses of the FT students. This was probably due to their heavy workload of their full time jobs as well as a lack of time and opportunities to carry out such discussions.

Preference on Type of Transparencies

Among the three options (see Table 5), both the FT and PT students revealed similar preferences on those transparencies, e.g., a mini-textbook as well as those only containing basic points. This was a further confirmation that the students wanted to be spoon fed.

Table 5: Summary Table for Q.15 — What type of transparencies do you like most?

Q.	Options	FT		PT		Row Total	
		No.	%	No.	%	No.	%
15	A. mini-textbook	12	19.4	17	27.4	29	46.8
	B. basic points	13	21.0	16	25.8	29	46.8
	C. no transparencies	1	1.6	3	4.8	4	6.4
	Column Total	26	42.0	36	58.0	62	100.0

Preference on Type of the Lecture Notes

Among the three options (see Table 6), most students preferred lecture notes in the format of a mini-textbook, i.e., the format actually adopted by the lecturer as best satisfying the student population (see the above section). From the results of Tables 5 - 6, we can observe that nearly 50% of the students would like the lecturer to prepare the transparencies and the lecture notes in the format of a mini-textbook. This again showed the students' passive attitudes towards their study. They preferred to obtain all the studying notes ready made by the lecturer instead of making any effort to make their own notes. Obviously this option is much less time consuming than reading their own textbook and searching and reading literature. It should be pointed out that such an attitude is generally detrimental to students' understanding since a deeper understanding can be acquired by digesting the material and expressing it by one's 'own words' in individual notes. However, our students generally lack the ability to take their own notes during the lectures, whereas they have little time for their own literature studies (see next section).

Table 6: Summary table for Q.16 — What type of lecture notes do you like most?

Q.	Options	FT		PT		Row Total	
		No.	%	No.	%	No.	%
16	A. mini-textbook	18	29.0	28	45.2	46	74.2
	B. basic points	8	12.9	6	9.7	14	22.6
	C. no transparencies	0	0	2	3.2	2	3.2
	Column Total	26	41.9	36	58.1	62	100.0

New Lecture Notes

This part of QT2 examines the means and standard deviations of student opinion on the new lecture notes, which were explored by the seven major modifications introduced to teaching the module QSSP (see earlier section in this paper entitled Modifications Introduced to Teaching the Module QSSP (Semester B)) and listed in Table 7. A five point scale (5,4,3,2,1) is used, with 5 meaning the highest level (see the table below).

Table 7: Means and standard deviations for Q.19-Q.25 — New lecture notes

Q.	ITEM	FT		PT		TOTAL	
		M	SD	M	SD	M	SD
19	1. Plan of the Lecture	4.0	0.9	4.2	0.8	4.1	0.8
20	2. Title & Relevant Chs of Major Textbook	4.2	0.8	4.2	0.7	4.2	0.8
21	3. Revision Questions	4.4	0.6	4.2	0.8	4.3	0.7
22	4. Hints to Tutorial Questions	4.6	0.5	4.3	0.7	4.4	0.6
23	5. Model Solutions for Difficult Questions	4.7	0.7	4.5	0.8	4.6	0.8
24	6. Basic / Optional Parts Indicated	4.5	0.7	4.1	0.9	4.3	0.8
*25	7. Diagrams / Tables in the Proper Place	4.7	0.5	4.2	0.7	4.4	0.6

* with statistically significant difference between FT / PT students

These data implied that most of the FT and PT students agreed to the greater usefulness of new lecture notes and the teaching methods over the old ones, especially for the hints to tutorial questions and model solutions for the more difficult questions. This also implied that the students lacked initiative in their study. Diagrams and tables in the proper place within text in the notes were perceived as very useful ('strongly agree'). This result justifies partially the effort put into restructuring the notes since the diagrams were placed separately from the handwritten text on the previous transparencies due to the convenience of copying them from books. The FT students appreciated this arrangement more strongly than the PT students. However, both FT and PT students did not perceive providing a plan at the beginning of a lecture as especially useful.

Reflection on Students' Own Study

For the reflection on students' own study, its means and standard deviations for the FT and PT students examined by the five items are indicated in Table 8. A five point scale (5,4,3,2,1) is used, with 5 meaning the highest level (see the table below).

Table 8: Means and Standard Deviations for Q.34-38 — Reflection on your own study

Q.	ITEM	FT (N=26)		PT (N=36)		TOTAL	
		M	SD	M	SD	M	SD
34	1. Read LT Notes	3.6	1.1	3.4	1.0	3.5	1.0
35	2. Read Corresponding Books' Chapters	2.7	1.0	2.9	0.8	2.9	0.9
36	3. Do Additional Reading	2.6	0.8	2.6	0.8	2.6	0.8
37	4. Work Revision Questions	3.2	1.1	3.0	1.1	3.1	1.1
*38	5. Solve Tutorial Questions in advance	3.4	1.1	2.7	1.0	3.0	1.1

* with significant difference between FT / PT students

These data implied that the students did not make many preparations or revisions on their study. They quite often read lecture notes after the lectures but only occasionally worked through the revision questions as well as solving tutorial questions in advance. FT students seemed to show more incentives in solving tutorial questions before tutorials. Both the FT and PT students rarely read corresponding chapters in textbooks or did their own additional reading after lectures. It therefore might be summarised that the students just did limited study for this course and lacked initiatives to explore or search for more knowledge in this module. As shown, the students' reflection on their study matched with their expectations towards the lecturer / tutor's spoon fed teaching (see the following two sections of this paper), which was a passive as well as an unhealthy studying attitude.

Difficulties in Study

This part of QT2 deals with the means and standard deviations for students' internal and external difficulties in their study. They were measured by thirteen items stated in Table 9. There were five items measuring internal difficulties, which included items 1, 7 and 11-13. The remaining eight items measured external difficulties, which included items 2-6 and 8-10. A five point scale (5,4,3,2,1) is used, with 5 meaning the highest level (see the table below).

Table 9: Means and standard deviations for Q.39-51 — Difficulties in your study

Q.	ITEM	FT		PT		TOTAL	
		M	SD	M	SD	M	SD
39	1. Little Background Knowledge	3.5	1.2	3.5	1.2	3.5	1.2
40	2. Insufficient Time to Digest Materials in LT	4.0	0.9	4.1	0.7	4.1	0.8
41	3. Insufficient Time to Revise	4.0	0.9	4.3	0.6	4.2	0.8
42	4. Heavy Workload in Other Subjects	4.0	0.7	3.8	1.0	3.9	0.9
43	5. Too Much to Read	3.5	1.0	3.6	1.0	3.5	1.0
44	6. Difficulty in Solving Revision Questions	3.2	1.1	3.3	1.0	3.3	1.0
45	7. Poor English Level	3.4	1.0	3.5	1.0	3.4	1.0
46	8. Difficulty in Learning Maths of this Module	3.4	0.9	3.3	0.8	3.3	0.9
47	9. Difficulty in Memorising Final Equations	3.7	0.9	3.5	0.8	3.6	0.9
48	10. Unclear Definitions of Important Terms	3.4	0.9	3.4	0.9	3.4	0.8
49	11. Difficulty in Understanding Basic Concepts	3.4	0.9	3.6	0.8	3.5	0.9
50	12. No Interest in this Subject	2.8	0.7	2.6	0.8	2.7	0.8
51	13. Poor Study Skills	3.0	1.0	2.8	0.9	2.9	1.0

These data revealed that most students were not concerned much with their abilities or study skills. The difficulties which they concerned most were (1) having insufficient time to digest the material during lectures as well as (2) revising the lecture notes / textbooks carefully every week. Most of them quite disagreed that they lacked of interest in this subject or had poor study skills. They fairly agreed with some of the difficulties: the workloads in other subjects were heavy, which

prevented them from preparing for the tutorials in QSSP; the final equations were too long to be memorised; there was too much to read for the lectures and tutorials; they received little background knowledge for this subject; and they encountered some difficulties in understanding several basic concepts in this subject. Contrary to the direct lecturer's experience with these students, whose command of English was generally very limited, the students appeared to agree less that their level of English was poor. The students appeared also to agree less that the important terms lacked clear definitions; the mathematics involved in this module was too difficult; or they had difficulty to solve the revision questions in the lecture notes. Therefore, this might be interpreted that most of the students did not perceive themselves as lacking the internal capability to study this course but mainly as having the external difficulty of insufficient time instead. It could be concluded that better time management was a crucial element in lessening their difficulties encountered in this subject and improving their study results. Finally, the students' passive studying patterns were also revealed in the results of Table 9 in relation to those of Tables 7 and 8. We observed that the students perceived more external difficulties than internal ones (Table 9) but they only did limited revisions for this course during the semester (Table 8). This passive studying attitude matched with their expectations towards the teaching of the lecturer / tutor (Table 7). They expected the lecturer / tutor to provide all study materials for them in a ready-made format so that they did not have to do any independent searches themselves.

Other Aspects

Due to the page limit for this paper, for data and detailed analysis on the following aspects please refer to the report (Rudowicz and Wu, 1996) as follows:

- Workload of the Course (Section 4.2.4)
- Mid-Term Test (Section 4.2.5)
- Suggestions for Modifications to the Teaching (Section 4.2.7).

The correlations between quiz marks and lecture topics as well as students' self-reflection on their study have also been studied. There are significant correlations found between quiz marks and the perceived quality of presentation of lectures and / or the perceived importance of topics for some lectures / topics (Rudowicz and Wu, 1996, Chapter 4.3.1).

Conclusions

Improving teaching is an ongoing process. As the new groups of students enter the University each year and science progresses as well as the educational research provides new techniques and ideas, lecturers must modify and improve their teaching. In the framework of the present project, we have attempted to address the broad spectrum of factors which influence the quality of teaching and learning.

Using the Action Learning Methodology, various aspects of teaching and learning have been investigated and substantial modifications have been introduced to teaching the module Quantum and Solid State Physics (Semester B). The analysis of the exam results and of student feedback have provided clear directions in this regard. It has led to deep changes in the module content and teaching methods. The most tangible outcome of these phases of the project are the revised lecture notes. The new teaching materials have provided a solid basis for better teaching and proved to be well received by students. Nevertheless, it can be envisaged that some minor adjustments may be needed next year.

For other university teachers, two other outcomes of this phase of project are of interest since they can be utilised to improve teaching in any module. First, the method of analysis of exam results can be used to identify teaching difficulties as well as problems with module content and

presentation of particular topics, etc., in any science module. As a follow up activity, a project on a computerised package to perform the statistical analysis required will be proposed in the near future. Second, the questionnaires used for the evaluation of the teaching modifications can be adapted to provide viable tools for assessment of teaching in other modules.

We hope that this summary of the main results of the present project, which are of general interest, may help to improve the quality of teaching in other modules as well as provide stimulating reading, which may generate further useful ideas in this regard.

Acknowledgments

This work has been partially supported by the ALP Research Grant (No. 875007). The authors thank Ms Jessie Yum and Mr Tak Shing Ha, the ALP team members, for their helpful suggestions and working out the layout of the questionnaires.