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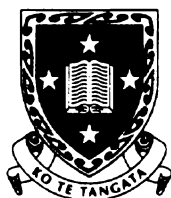
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Improving Teaching and Learning of University Physics in Taiwan

A thesis
submitted in fulfilment
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of
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at the
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by

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Abstract

This thesis studies the teaching and learning of first year university physics. The students involved in this study were first year physical science or engineering students at a private university in Taiwan. These students appeared to possess a low motivation towards learning university physics and had a poor academic performance. The failure rate was of concern to both the students and their lecturers. The existing teaching design, which included the physics content, the didactic teaching approach, and the assessment emphasising recall of facts, were seen to have contributed to the situation.

These problems are also found in the literature mostly in western countries. The literature which is specifically related to university physics education, provides information about the prevalent problems of traditional teaching in university physics courses, as well as trends for modifying the existing course. These modifications are mainly in the aspects of teaching content and teaching approach design. This literature provides practical suggestions for innovations to university physics courses.

The literature on constructivist and sociocultural views of learning in science education indicates that learning physics involves both cognitive engagement and engagement in learning as a social practice. The role of a physics lecturer is seen to shift from simply an information provider and concept interpreter, to a learning mediator, which includes facilitating students' engagement in the learning process, monitoring students' learning outcomes, and intervening in students' alternative conceptions. Accordingly, students need to play an active role in their learning, ie, to actively participate in learning, and to reflect and be aware of their learning outcomes. Therefore, the literature suggests that the focus of physics classes needs to shift from teaching alone to both teaching and learning. The goals of learning physics include developing students' physics knowledge as well as promoting learning motivation and broadening the students' perspectives of why and how to learn physics. This literature provides a theoretical framework for this thesis regarding the learning process, teaching tasks, and the goals of the university physics course.

This study includes three phases:

- (1) understanding the existing situation, including both the students' and the lecturers' perceptions with respect to the course design, the teaching performance, and the learning outcomes. The students' opinions were investigated by a questionnaire survey, and the lecturers' views were investigated by interviews and a questionnaire survey. Two standardised tests were also applied in order to examine the students' physics background in comparison with their peers in the United States.
- (2) designing and implementing an intervention teaching program. The design of the intervention program was based on the literature on constructivist and sociocultural views of learning and the existing situation as identified by this research. The major theme of the program was to activate the students' participation in the classroom learning process. A three-week intervention teaching program was then implemented in one class by the researcher.
- (3) evaluating the outcomes of the intervention program, which included student interviews, a questionnaire survey, and standardised tests. The outcomes of the intervention teaching were compared with those of traditional teaching.

This study concludes that the learning outcomes of the traditional teaching appeared to be far from satisfactory both in cognitive and affective aspects. The students obtained low gains in standardised tests before and after teaching. Meanwhile, the students' learning motivations and adopted learning strategies appeared to drastically deteriorate during the learning process. The evaluation of the intervention teaching showed that the new teaching design significantly improved the students' learning motivation, promoted the students' engagement in thinking and discussion, and enhanced learning commitments out of class. Meanwhile, the students' perceptions and awareness of their learning were enhanced by the intervention teaching. However, the intervention students were found to have similar achievement in physics knowledge as their peers in the traditional classes.

Dedication

僅以此文獻給我懷念的父親：張春東

感激他曾對我毫無保留的提攜及栽培，他超越傳統的遠見促成了我今日的成果。

To the memory of my father: Chun-tong Chang

My father encouraged me and supported me in every way, to study for my Master's Degree in the United States at a time when most people in the Taiwan society did not value higher level of degrees for girls. The experience of 15 years ago opened a window to the western world for me and became the seed for this doctoral project. What I have achieved now is due to my father's broad perspective.

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Chapter 1

Introduction

All is not well with university physics education in Taiwan. As a physics lecturer at Feng-chia University in Taiwan, teaching the first year university physics course for physical science and engineering students, my experiences of teaching this course had not been enjoyable but rather dissatisfying and discouraging. I had concerns for the students as learners, the teaching, and the course design.

The following section outlines my concerns and why the research was undertaken.

1.1 Concerns

- *The learners*

My concerns for the students included their low motivation for learning, their passive attitudes to learning and their unsatisfactory academic achievement.

In their learning attitudes, many students appeared to be lacking in engagement and interest, and to be dependent on the teacher for learning. According to my teaching experience, although most of the students appeared to be highly motivated at the incoming stage, their motivation drastically reduced shortly after the course commenced. Some students perceived the university physics course as high school physics, plus calculus and in an English format. They perceived nothing new in the physics content compared to their previous high school physics.

It was not surprising then that students did not ask questions during the 50 minute lecture, even when I as lecturer actively encouraged their questions. Most of the time, the students only expressed their ideas in class when they were called on to answer questions. The students almost always remained silent in class, whether concentrating on the lecture or not.

As the semester went on, the students became less and less engaged. The attendance rate often decreased drastically to about 50% during the second semester, if I was not taking a roll call. The embarrassing dozing problem became more and more prevalent in mine and other university physics classes, and as colleagues, the physics lecturers often shared their tips for “curing” dozing. Meanwhile, during the 10-minute break between the two consecutive physics lecture hours, it was not unusual to see that the majority of the students had prostrated themselves on the desk. The course seemed to be too tedious to retain their attention, let alone induce their interest.

To provide opportunities for students to consult with the lecturer personally, I usually stayed in class for a couple of minutes after finishing the lesson. But very often, there were no inquiries at all. Occasionally, there were a few students who came to consult, but most of their questions were limited to the examination domain. It seemed as though performance in the examination was the only concern for most of the students studying this course. It was very unusual for any students to come to discuss the topics just for personal interest or out of curiosity. The students’ perceptions of the course appeared to be very different from those of the lecturers who would regard their course as full of wonder, thrilling, and worthy of enthusiastic exploration.

Although the examination was the only concern for most of the students, it did not imply that their academic performance was satisfactory. The failure rate was about 25% in the first semester and then increased to over 30% in the second semester. This failure rate was despite the lecturers’ generous adjustment of the marks. When marking their examination answers, it was common to see the students respond with some irrelevant formulas without any attempt to illustrate the phenomena and approach the corresponding concepts. Their answers indicated that many of them might have only stored several meaningless symbols in their brains without linking them to the corresponding concepts. This result may have been a reflection of their learning habits. Many students had no regular study habits, but only “crammed” for the examinations. Memorizing “hot formulas” and the solutions to “hot problems” were the main learning tasks for many of them.

Therefore, I had concerns for the students' affective and cognitive learning outcomes.

In addition to my personal experience of the low engaged students and unsatisfactory academic performance, I found that the results of the students' evaluation of my teaching did not improve, even as my teaching experience gradually accumulated. I started to seek research resources with respect to university physics education, but there was a lack of information relating to the situation in Taiwan. Most of the research articles found related to western countries, and their considerations may not be relevant to the Taiwanese context.

The problems mentioned above that the researcher faced, may be commonly perceived by many other physics lecturers as well as by a sizable number of the students. In Taiwan, physics education research at the tertiary level has been seriously neglected in contrast to the abundant studies of secondary level.

A consideration of the students' background is also important.

In Taiwan, about 60 % of the university students are required to learn university physics, and the majority of these students are majoring in science and engineering. There are about 40,000 students studying in the university physics for science and engineering course every year (Taiwan Education Resource 1999).

At Feng-chia, the students taking this course were majoring either in Science (20%) or Engineering (80%), and they were mostly selected through the University Entrance Examination. About 60% of the high school students in Taiwan can successfully enter a university. The students will select their academic majors before entering. The students' average academic level at Feng-chia University is located around the average for all university students, but their levels are widely spread with respect to different majors. The students are grouped into the same class according to their major, and the courses in the first year of university study are all compulsory. Therefore, these first year students meet with the same group of classmates in all of their classes, and peers can become acquainted in a short time.

Most of the students come straight from high school. They are homogenous in

their ages (18-20) and previous study experiences. In Taiwan, the teaching approach at both secondary and primary school levels normally involves the traditional transmission method of teaching to ensure that the students can “absorb” the most knowledge within the limitations of the teaching time. Therefore, based on their previous learning experiences, the students may see no problems with this type of didactic teaching approach being used at university.

Meanwhile, although the university entrance rate is now higher, the study pressure for the candidates remains extremely high. Most of them have to study as much as 12 hours per day without any leisure; they even need to sacrifice normal sleeping time. It is commonly perceived by the students that the last year of high school study is the hardest time of study throughout their life.

After the “hard time” preparing for entering university, the life of university study is expected by students to be more relaxed and more flexible. The first year engineering students are normally required to take 20-25 hr/wk courses, and university physics is usually regarded as one of the most important courses by the first year students.

- ***The teaching***

My second concern was with the teaching of university physics. Firstly, the teaching environment appeared to provide little support and many constraints for the teaching.

The university administration policy tended to emphasize the research and underplay the teaching tasks of lecturers. Achievement in research is encouraged by all sorts of rewards: promotion, reputation, and bonuses. In addition to the practical rewards, research is also regarded by most lecturers as much more intellectually demanding than teaching.

Although the university provided prizes every year for outstanding teaching, the selection procedure of the candidates was problematic. The receivers of this award were nominated and selected by all lecturers, most of whom had never visited their colleagues' classes. It was not surprising therefore that the winners were those who had good inter-personal relationships with their colleagues. Although

the university distributed questionnaires to students to evaluate their satisfaction with the teaching, the results were only provided as a soft reference and did not contribute to the lecturers' records.

In addition to the lack of support for the teaching from the university management, teaching flexibility was also seriously restricted by a unified policy. The Physics Teaching and Research Centre at Feng-chia had established a unified curriculum policy. There are 11 physics lecturers at Feng-chia University, and the unified policy had tied them to a unique curriculum design. Under this policy, all physics lecturers were required to cover the assigned teaching content, and the examinations were the same for all students. The assigned teaching content and examination were discussed and negotiated by all physics lecturers. Therefore, no lecturer had any flexibility to apply his/her own ideas in teaching content and assessment design, unless s/he could convince the majority of his/her peers. Meanwhile, the assigned content was usually so heavy that there was little discretionary time for lecturers to try different teaching approaches, other than didactic transmission.

The original purposes for setting this unified policy were to ensure that all students had the same standard of assessment, and to monitor the teaching content covered by all lecturers. However, the unified policy also restricted the flexibility of lecturers' teaching design, as well as their considerations of the heterogeneity of the students. The unified policy strictly limited the lecturers who intended to improve the existing poor learning outcomes, but also provided excuses for others to impute the responsibility of improvement to the whole system rather than to themselves.

- ***The course design***

Every year there are around 2000 students taking the university physics course at Feng-chia University. It is the highest enrolment for this course amongst all universities in Taiwan. As in many other countries, it is a pre-requisite course for all science and engineering students.

The university physics course is usually a two-semester course, with each

semester consisting of 15 weeks. The course includes two components: lectures and laboratories. Unlike many other countries, most of the universities in Taiwan do not provide tutorial sessions for this course. At Feng-chia, all students in this course are required to attend a 3 hr/wk laboratory. Two types of lecture courses are given, 2 hr/wk and 3 hr/wk, and the latter is more common at Feng-chia, as well as at other universities.

The size of the lecture class is the same as that of the laboratory class, which includes about 55-65 students. At Feng-chia University, there are about 35 lecture classes and 35 laboratory classes. Sharing the teaching of these classes has become the main teaching task for the 11 physics lecturers. Each lecturer is assigned to teach about 8-9 hours of lectures and 6-12 hours of laboratories per week.

In the lecture classes, the lecturers usually use traditional transmission teaching methods. The lecturers' main teaching task involves solving problems on the board, and demonstrating the mathematical skills and explaining the corresponding concepts, while the students usually focus on listening and copying notes. Due to the large class size, the heavy teaching load, and the didactic teaching method, many lecturers suffer from sore throats even to the extent of needing to use a microphone in class. Tips for curing sore throats are popular and are shared by lecturers.

The assessment method is limited to traditional written examinations, which focus on problem-solving. The students' grades are evaluated according to three components, the mid-term examination, the final examination, and quizzes. Mid-term and final examinations constitute 70% of the students' final grades, and are given in a unified format. The unified examination means that all students sit the same examinations which are designed by all of the lecturers. Therefore, each lecturer only has flexibility when designing their own assessment tools for quizzes, which contributes the remaining 30% of the grades. Alternative considerations of assessment tools include oral examinations, essays, independent study projects, real life questions which may not have a unique answer etc, but these are hardly ever seen in the university physics classes.

The course relies heavily on the conventional American edition textbook. The textbook dominates the teaching materials as well as the assessment design. The level of the physics content of the textbook may not be a problem to the Taiwanese students, but the English language becomes a significant barrier for them in learning physics. The students have not used textbooks in English until entering university. Meanwhile, the textbook is usually very lengthy, and some textbooks are over 1800 pages long! Physics lecturers are faced with the dilemma of covering the content whilst maintaining a reasonable teaching pace which caters for the students' learning ability. The authority of the textbook makes lecturers feel guilty when omitting some topics, which is inevitable due to the teaching time constraints.

This section has briefly introduced my concerns with the students, the teaching, and the course design. The next section will provide an introduction to the research rationale

1.2 The rationale for the research

The rationale for the research will be briefly explained in two sections: (1) research aims, and (2) research questions.

1.2.1 Research aims

Given the concerns, there were two major aims for this research:

Firstly, this research aimed to obtaining a better understanding of the existing situation of the university physics education in Taiwan.

As mentioned above, there was a lack of research in the area of university physics education in Taiwan. Although the researcher has had many years of teaching experience, this experience was not sufficient to establish a sound understanding of the existing situation in teaching and learning. In her position as a lecturer, the researcher may be equipped with better knowledge about lecturers' opinions than those of students. Therefore, a research-based investigation of the existing situations, from both of students and lecturers' points of views, with respect to

teaching and learning was required before any attempt to improve the outcomes.

Secondly, this research aimed to develop ways to improve the learning outcomes of university physics in Taiwan. This research aim was approached by two steps: (1) to design and implement an intervention teaching program, and (2) to evaluate the learning outcomes of intervention program with respect to those of the traditional teaching.

1.2.2 Research questions

This section describes the research questions corresponding to the research aims explained above. There were three main research questions with several sub-questions.

- (1) What was the existing situation in university physics education in Taiwan?
 1. What was the initial situation of the incoming students, including their expectations, attitudes, and perceptions toward to course as well as their physics backgrounds?
 2. What were the students' perceptions of learning in traditional university physics classes: the teaching, the course overall, and the learning?
 3. What were the physics lecturers' perspectives of teaching the course and comments on students' learning?
- (2) What was an appropriate intervention program design, to fit the context of the course, and to take into account existing research, to improve teaching and learning physics?
- (3) What were the results of the evaluation of the intervention program compared with those of the traditional teaching?
 1. What were the differences between the students in the intervention program and students in traditional classes, in their academic achievements, evaluations of the course, and attitudes and commitments of their learning?

2. Were there barriers to modifying the teaching?

1.3 The outline of the thesis

This thesis consists of 10 chapters.

A brief introduction with respect to each chapter is given below.

Chapter 1 gives a brief introduction of this research and the outlines of each chapter.

Chapter 2 reviews the related literature, which provided a theoretical framework of the constructivist view of students' learning, and outlines the practical issues in teaching innovations in university physics courses worldwide. A theoretical framework of this thesis is then proposed.

Chapter 3 addresses the design of this research methodology. The research activities are explained in two formats. The first is based on the three main research questions and organizes the research activities into three steps. The second format is chronological, and includes three phases of the research.

Chapter 4 analyzes and discusses the students' situation in the traditional teaching environment. Five points are discussed: (1) the incoming students' expectations of the course and their own learning, (2) the students' high school physics background, (3) the students' evaluation and perceptions of the course, (4) the mismatch between the students' expectations of the course and the actual course design, and (5) the deterioration in learning attitudes.

Chapter 5 documents the lecturers' views. This chapter consists of four parts: (1) the lecturers' opinions with respect to the course design, the goals of the course, the content design, and the teaching approach, (2) the lecturers' perceptions of the learners: learning motivation, possible learning barriers, and the learning process, (3) the lecturers' suggestions for teaching improvement, and (4) the lecturers' comments and shift in opinion with respect to the students' views.

Chapter 6 summarizes the findings of both the students' situation (Chapter 4) and

the lecturers' views (Chapter 5), which provides a sound background understanding of university physics education in Taiwan. In addition to comparing the coherence and disparity between the two groups, this chapter also evaluates the opinions of both the students and the lecturers with respect to the literature.

Chapter 7 describes the design and implementation of the intervention teaching program. Although the intervention teaching design is part of the methodology, it is separated from Chapter 3, since the intervention design was partly based on the background understanding summarized in Chapter 6. This chapter includes four parts: (1) the conditions of the teaching environment, (2) the principles of the design, (3) the design of the teaching content and approach, and (4) the implementation of the program.

Chapter 8 presents the quantitative evaluations of the intervention program mainly based on the results of the survey. This chapter includes four main parts: (1) the students' affective learning outcomes, (2) the students' academic achievements, (3) the students' perspectives of and attitudes towards learning, and (4) a summary of the significant findings of the intervention program.

Chapter 9 examines the outcomes of the intervention teaching by qualitative evaluation based on the data from the student interviews. This chapter discusses the intervention students' opinions under four headings: (1) teaching content design, (2) teaching approach, (3) students' perceptions of learning, and (4) a summary of the students' opinions with respect to the intervention program, and suggestions for further modification in teaching design.

Chapter 10 concludes the findings of this research, which includes (1) a summary of the significant findings of this research, (2) the implications of the findings, and (3) suggestions for further research.

The next chapter will review the literature which is related to this research.

Chapter 2

Literature review

This chapter describes the theoretical framework of this research, which comprises three parts:

- (1) a review of the existing literature relating to university physics education,
- (2) a summary of learning theories based on the existing literature,
- (3) a description of the thesis of this research.

The existing literature relating to this study comprises of two main streams. One area is the research directly related to the practical issues of curriculum design in the context of university physics education. This area of literature is mostly contributed to by physics lecturers, and the majority of the research has been carried out in the United States. The other area is general science education research, which includes a focus on interpreting, understanding, and theorising students' learning. This group is dominated by constructivist science educators. Although these two groups both aim to enhance learning outcomes, their research foci and formats are significantly different. The university physics education group usually conducts empirical studies regarding ways to improve students' academic performance in university physics, while the general science education group focuses on providing an insight into the learning process to inform teaching. These two streams of literature, university physics education and general science education, are discussed in detail in sections 2.1 and 2.2 respectively.

In section 2.3, based on the literature of general science education, three views of learning are summarised with a following discussion of the implications for teaching and curriculum design. These views of learning are (1) the behaviourist, (2) the personal constructivist, and (3) the sociocultural views of learning.

Finally, in section 2.4, the thesis and the research questions are presented.

2.1 Research in university physics education

There has been much research carried out into the problems with and the possible solutions to teaching physics at the university level. The research directly linked to university physics education provides a better understanding of the practical issues of curriculum design in relation to learning outcomes. This literature will be discussed in five sections:

- (1) understanding the background and the existing problems,
- (2) expected goals of university physics courses,
- (3) innovations in content design,
- (4) modifications to the traditional teaching approach, and
- (5) critiques of the university education research

2.1.1 Understanding the background and the existing problems

Many studies report the background and existing problems of university physics education. These problems can be categorised as: (1) the incoming students, (2) the curriculum design, and (3) the learning outcomes.

- ***The incoming students***

In the first group of research studies, the students, and specifically their academic backgrounds and their learning attitudes, are perceived to be the problem.

According to this research, the background of the first year physics students is not only insufficient on average, but also diversified in terms of proficiency in physics among students in the same class (Kurz, 1997; Redish, 1996; Ridgen, 1997). This problem is mainly due to the dramatic expansion in university student numbers since the early 1990s, which has been acknowledged in many countries, such as the United Kingdom (Stewart, 1995), the United States of America (Redish, 1996), Germany (Kurz, 1997) and Hong Kong (Sun and Lau, 1996).

In addition to the problem of a lack of proficiency in physics, most of the first

year students were also found to possess passive attitudes towards learning. White, Gunstone, Elterman, MacDonald, McKittrick, Mills and Mulhall (1995) found that many of the first year students were dependent on notes and the lectures, reluctant to consult the lecturers, and limited their learning effort to obtaining a passing grade only. Prosser, Walker and Millar (1996) found that a high proportion of the university physics students adopted a “surface” approach to learning, in terms of attending classes, reviewing notes, learning formulas and doing exercises. It was also found that few students were seeking understanding of how the physics principles related to their experiences in the real world (Prosser, Walker and Millar, 1996; Redish, Saul and Steinberg, 1998).

These two problems of insufficient academic background and passive learning attitudes were found to be directly linked to the students’ poor academic performance. Rowell, Dawson and Pollard (1993) found that the students’ physics background and learning attitudes constitute a reliable indicator for identifying the students who are likely to be failed in their final grade. They called these students “high-risk” students.

- ***The curriculum design***

The second perceived problem identified in the research literature is that of the curriculum design. Curriculum design is seen as comprising of three parts: content design, teaching approach, and assessment. Prosser, Walker and Millar (1996) noted that course structure, teaching approach and assessment all have an impact upon students’ perception of how (the method) and what (the contents) to learn, and that the students’ perceptions are crucial to their learning strategies and thus their learning outcomes.

The first concern is about the content included in university physics courses. These concerns about content can be summarized as follows:

- (1) The content is dominated by mathematical derivation rather than concept clarification (Forinash, 1991; Hewitt, 1994; Linder and Hillhouse, 1996; Meltzer and Manivannan, 1996);
- (2) The course tries to cover too much content (Amato, 1996; Elton, 1997;

Ridgen, Holcomb and Di Stefano, 1993; Tobias and Hake, 1988),

(3) No links are made among different topics (Coleman and Griffith, 1997; Donald, 1993; French, 1988; Prentis, 1996), and

(4) The content focuses on classical topics and neglects modern physics (Bartlett, 1988; Hilborn, 1988).

Details about suggestions to modify the existing content of the courses will be discussed later in section 2.2.3

The second concern relating to curriculum design is with the didactic teaching approach, and the “passive” learning activities, ie, students’ tasks are mainly limited to copying notes verbatim from the board and/or watching demonstrations rather than being actively involved in questioning and explaining concepts. Elton (1997) and Zollman (1996) were critical that many physics lecturers act as if the students, as passive receptors, are to be “filled up” with content. In university physics courses, students are mostly expected to actively process the new knowledge, not in, but out of, the class (Redish, 1996). Gautreau and Novemsky (1997) noted that learning was the “neglected child” of traditional physics teaching. In other words, lecturers regard their tasks in class as mainly giving lucid lectures, while little effort and awareness are put into retaining students’ engagement in learning in class.

The third concern relating to curriculum design is the assessment strategy and orientation. An abundance of education studies claimed that students’ perceptions of assessment requirements direct their approach to learning and affect their learning outcomes (eg, Boud, 1990; Entwistle and Entwistle, 1991). In his study in South Africa, Linder (1993b) found that 40% of the students taking university physics adopted a rote learning strategy to memorize the formulas and calculations, without understanding the concepts behind them. In the United States, Zajchowski and Martin (1993) and Di Stefano (1996) found that the “plug-in” calculation style of examination misguided the students towards searching for “hot” formulas without thinking about the phenomena. The emphasis of the examination can also determine the students’ learning agenda (French, 1988). In

summary, while assessment is regarded as an effective tool in increasing learning efforts by the majority of lecturers, the literature is highly concerned that the conventional assessment design misguides the students towards a superficial learning strategy.

- *The learning outcomes*

The third group of studies on the problems with university physics education is that describing learning outcomes. Learning outcomes were found to be unsatisfactory in the areas of academic performance and learning attitudes.

With respect to academic performance, many studies addressed their concerns about the high failure rate, which is claimed to be 30-40% (Holton and Horton, 1996; Rowell, Dawson and Pollard, 1993; Tobias and Hake, 1988). Many physics lecturers were forced to lower the required standard to avoid failing too many students (Redish, 1996), whereas French (1988) was critical of the fact that some physics lecturers even proudly regarded the high failure rate as natural attrition of a tough course.

With respect to the students' emotional reactions to the university physics course, the learning process was found to drastically deteriorate students' learning attitudes, such as students taking responsibility for their own learning. In addition, learning efforts dramatically declined in comparison with the students' original expectations (Redish, Saul and Steinberg, 1998).

In summary, the background of university physics education as described in the literature, tends to be negative. The incoming students are perceived to be unprepared both academically and emotionally, and an inappropriate teaching design is seen as contributing to the deterioration of the situation. In addition, learning outcomes have been found to be unsatisfactory.

Suggestions for modifying curriculum designs to achieve better learning outcomes have been made. However, the expected goals of the course need to be discussed first in order to provide the criteria for teaching modifications. The next section will discuss the goals of the university physics course as summarized from the literature.

2.1.2 Expected goals of the university physics course

Elton (1997) and Osborne (1976) noted that the goals of a course need to be clarified first when discussing course design. In his review of the literature regarding the teaching effectiveness of different teaching approaches, Dunkin (1983) noted that teaching effectiveness depends on what goals are expected to be achieved. Therefore, it is necessary to deal with the expected goals before discussing the issues of content design, teaching approach, and assessment (Cross and Angelo, 1992; Elton, 1997; Osborne, 1976).

Many articles suggested goals for the university physics course, specifically in the areas of knowledge acquisition and learning capacity development. Elton (1997) argued that many physics lecturers usually think of content (to be taught and learnt) rather than objectives (to be achieved by the students) when discussing teaching goals. The objectives of the university physics course need to include outcomes (some physics concepts, such as understanding the concept of force) and processes (personal development, such as ability to think and/or communicate). Donald (1993) studied some physics lecturers' views with respect to the teaching goals of university physics courses and these can be summarised as:

- (1) knowledge goals: These were to develop students' physics knowledge, focusing on better comprehension rather than an increase in physics concepts,
- (2) intellectual capability goals: These included an improvement in the ability for description, selection, representation, inference, synthesis and verification,
- (3) learning attitudes goals: These included developing students with positive attitudes towards physics and learning in general.

The expected goals of the course, other than knowledge acquisition in physics, are similar to the goals of higher education in general. These goals are to enrich the students' abilities and motivations for lifelong learning (Cross and Angelo, 1992; Ramsden and Martin, 1996). Ramsden and Martin (1996) identified three goals for higher education: (1) independence, (2) critical thinking, and (3) willingness to learn. A number of studies in higher education criticise the fact that in traditional

forms of university instruction, students are often encouraged to memorise and reproduce “inert” knowledge, which is unlikely to be transferred to complex problems of working life (eg, Allan, 1996). Professional workers, who often work in teams, require communication and cooperation skills, and they are also required to integrate theoretical and practical knowledge, to be able to search for new knowledge, apply it and transform it to novel uses (Tynjala, 1998).

In summary, the teaching goals of the university physics course are not only related to knowledge acquisition but also to personal, generic development, such as integration and application of knowledge, willingness and ability to search for new knowledge, communication ability etc. Therefore, when considering teaching design, the learning process becomes as important as the students’ immediate gain in physics knowledge (Biggs, 1996; Elton, 1997; French, 1988; Hammer, 1995b; Keeves and Aikenhead, 1995).

The next two sections discuss suggested modifications to the university physics course design in order to match the expected goals. The modifications will be categorized into content design and teaching approach, and will be discussed separately.

2.1.3 Innovations in content design

According to the literature, innovations in university physics education were found to have two different themes. In the earlier innovations, the focus was more on teaching content: textbook design, content structure, selection, and coverage. These studies were mostly published in the 1980s and early 1990s. Since 1990, physics educators have broadened their focus from content only to teaching approaches. This shift may have been influenced by the development of a constructivist view of learning by the science education community. The programs focusing on content modifications are discussed in this section, and modifications to teaching approaches will be detailed in the next section.

An example of research in the 1980s on the content of university physics was the Introductory University Physics Project (IUPP). This program took four years to prepare (1987-1990) and was implemented for three years (1991-1993) at eight

US institutions (Coleman and Griffith, 1997; Ridgen, Holcomb and Di Stefano, 1993).

The IUPP was based on three fundamental principles:

- (1) less is more: The existing content coverage was seen to far surpass the students' ability to learn. Therefore, reducing the teaching pace and coverage became a way of enhancing learning outcomes.
- (2) a story-line for coherence: Although physics lecturers view physics content as integrated, the students perceived few links amongst concepts. Physics content were seen as needing to be presented as a coherent structure linked by a story-line to help students form a global picture of physics concepts.
- (3) modernising the content: It was felt that introducing modern physics into the course was needed to avoid the impression of the course being out of date. Some classical topics needed to be omitted.

In addition, there were some other concerns for the IUPP developers. Firstly, the need for non-traditional problems was proposed. Lecturers need to design more context-rich questions to link the contents to the students' real lives and promote learning interest. Secondly, the use of computers in improving learning outcomes was considered. Thirdly, the IUPP program addressed the request for the physics lecturers to incorporate learning research into course design (Coleman and Griffith, 1997; Ridgen, Holcomb and Di Stefano, 1993).

At the same time, many physics educators in different countries expressed their opinions about the teaching content of university physics courses. Some of their opinions were in accordance with those of the IUPP. Additional suggestions can be briefly summarized as follows:

- (1) Many physics educators were concerned that the physics content was too mathematics-orientated, and suggested that physics lecturers should put more effort into helping students clarify their understanding of physics concepts (eg, Forinash, 1991; Hewitt, 1994; Meltzer and Manivannan, 1996);
- (2) In order to improve the students' understanding of concepts, it was suggested

that teaching physics should emphasize verbal descriptions rather than be dominated by symbols (Kalman and Kalman, 1996; Linder and Hillhouse, 1996; Tobias, 1989);

(3) Many physics educators expressed their disagreement with existing standard university physics textbooks and called for a change. The major criticisms included the fact that:

1. textbooks tend to cover too many topics: The subject of physics has been developed by scientists for more than 300 years; it has become massive in content (Hilborn, 1988). Amato (1996) and French (1988) argued that the textbook has become an encyclopedia rather than a textbook.
2. textbooks tend not to be well integrated: The physics content is presented as discrete pieces rather than as a coherent picture linking concepts (French, 1988; Di Stefano, 1996; Amato, 1996).
3. textbooks tend to contain too much jargon, too many symbols, and insufficient explanation to aid understanding (Tobias and Hake, 1988). Hestenes, Wells and Swackhamer (1992) noted that many US students have difficulty in understanding the physics textbook.
4. textbooks tend to ignore pedagogical theory: Most of the authors of the university physics textbooks are physicists who lack pedagogical knowledge. As a result, conventional textbooks appear to be dominated by a transmission view of learning as the corresponding real-life contexts are mostly absent. This deficiency can greatly reduce learning outcomes (Langenberg, 1997; Ridgen, Holcomb and Di Stefano, 1993; Tobias and Hake, 1988).

Although many criticisms regarding the textbooks were made, they have continued to play a central role in instruction (Hynd, 1994).

On the other hand, there were some physicists who expressed opposing opinions to the above arguments. Although these opinions were not largely found in education journals, their opinions may be prevalent amongst physicists and a

majority of those teaching university physics. These opinions may be crucial to the implementation of content innovations. Their main arguments are that: (1) traditional lecturing is an efficient way to expose the students to necessary materials; (2) to cover most of the content is the physics lecturers' responsibility; (3) mathematical ability is essential to maintain the "quality" of the course; (4) good lecturers are not equivalent to popular lecturers: consideration of learners' interest may result in a deterioration of learning quality, and (5) a full understanding of classical physics by students is required before introducing modern topics (Jones, 1996; Jones, Daniels, Chasnov, Chabay, Sherwood, Raymond and Blyth, 1997).

In summary, other than the IUPP program, the articles mentioned above mainly expressed personal opinions, rather than reporting on actual conducted research investigating the outcomes of content modification.

The next section will discuss some research programs related to the university physics course. The discussion will focus on modifications to teaching approaches.

2.1.4 Modifications to the traditional teaching approach

Many physics education researchers have contributed to modifications of the teaching approach in university physics courses. Influenced by the development of a constructivist view of learning (eg, Hewson, 1981; Osborne and Wittrock, 1985; Posner, Strike, Hewson and Gertzog 1982), which highlights the essentiality of learners being engaged in deep-level cognitive processing, these physicists have focused mainly on promoting the role of learners in classes.

McDermott (1993) summarized many findings in physics education research, and pointed out that:

teaching by telling is an ineffective mode of instruction for most students. Students must be intellectually active to develop a functional understanding. (p.297)

She also reminded the lecturers not only to focus on what to teach but also on how to teach, and emphasized the importance of teaching that takes into account

students' thinking, feeling and needs.

In a survey consisting of more than 6000 students, Hake (1998) studied the differences in the students' understanding of mechanics concepts as a result of both traditional lecturing and Interactive Engagement instruction. He found that the latter achieved significantly better performance than the former, with a two standard deviation difference. He defined the Interactive Engagement instruction as

students are active in heads-on (always) and hands-on (usually) activities which yield immediate feedback to the students through discussion with peers and/or instructors. (p.65)

In Interactive Engagement classes, students are always asked to work cooperatively on conceptual questions and/or problem-solving (heads-on), while usually accompanied by operating experiments and/or using computers to verify their concepts (hands-on). The Interactive Engagement instruction was found to be successfully brought to a large class setting in a cost-effective manner by many researchers (eg, Heller, Keith and Anderson, 1992; Van Heuvelen, 1991).

Summarizing from the literature, a comparison of traditional lecturing and an interactive teaching approach is described as follows (eg, Gautreau and Novemsky, 1997; Heller, Keith and Anderson, 1992; McDermott, 1993; Redish, 1996):

(1) Characteristics of traditional lecturing include:

1. Treating the mind as an empty vessel, and viewing the learning process as the pouring in of knowledge, ie, a transmission view of learning;
2. Lecturers devoting themselves to giving lucid lectures, and doing demonstrations, while their students are expected to behave as passive spectators;
3. In class, students focusing on the lecturer and the teaching content, and working individually and competitively;
4. Lecturers working hard on teaching, but often forgetting about learning, ie,

they equate teaching with learning.

(2) In contrast to the traditional lecture format, an interactive instruction has the following characteristics:

1. Learning is regarded as requiring learners to actively construct the meaning of physics concepts based on their prior understanding of the world. What lecturers teach may not match with what students learn. Students need to play a central role in the classroom activities, and the lecturer takes the role of mediator to guide, facilitate and intervene in the learning process;
2. Teaching tasks include providing time and real-life questions for students, and cultivating a supportive classroom atmosphere to promote interaction between students and lecturers, and to encourage engagement in thinking to construct physics conceptions;
3. In class, students focus on their learning, and work cooperatively and collaboratively;
4. Lecturers do not value their talking for too long, depriving students of valuable time to think and discuss.

Key notions of the above summary are listed in Table 2.1.

Table 2.1 A comparison between traditional lecturing and interactive instruction in university physics courses

	Traditional lecturing	Interactive instruction
Learning process	<ul style="list-style-type: none"> ● Through information transfer 	<ul style="list-style-type: none"> ● Through learners' construction of the physics conceptions
Teaching task	<ul style="list-style-type: none"> ● Presenting information 	<ul style="list-style-type: none"> ● guiding, monitoring, and intervening in learning
Learning task in class	<ul style="list-style-type: none"> ● Receiving information from lecturers 	<ul style="list-style-type: none"> ● Constructing new conceptions based on prior conceptions and linking them to a coherent framework
Learning style	<ul style="list-style-type: none"> ● Individual and competitive 	<ul style="list-style-type: none"> ● Cooperative and collaborative

A few teaching projects in university physics which have addressed the above criteria of interactive instruction, have been studied (Redish, 1996). For example:

- (1) Peer Instruction (Mazur, 1996): This method was designed and has been implemented by Mazur at Harvard University since 1991. He divides the lecture hour into 15 minute chunks. Each chunk begins with a 10 minute lecture that ends with a short qualitative question. Students have 1 minute to think individually and answer the question and 2 minutes to justify their answers in discussion with their neighbours. In the last 1 minute the instructor guides the class to the correct answer.
- (2) Workshop Physics (Laws, 1989): This method included four learning sequences, which required students (1) to predict a phenomenon, (2) to develop a physics theory, (3) to perform an experiment to verify/adjust their theory, and (4) to apply their understanding in problem-solving.
- (3) Cooperative problem-solving (Heller, Keith and Anderson, 1992): This method provided a supportive environment to large classes of students practicing solving-problem. The problems were closely related to everyday life experiences, which were different from traditional end-of-chapter problems. The students were grouped into 3-4 members per group with the members working cooperatively to help each other integrate physics concepts to solve the problems.

In addition to Hake's (1997) study, many studies have evaluated the learning outcomes in academic performance under an interactive instruction, and compared it with those of traditional lecturing. They also found significantly positive results, indicating the strength of the interactive instruction (eg, Gautreau and Novemsky, 1997; Heller, Keith and Anderson, 1992; Meltzer and Manivannan, 1996). However most of the studies were concerned more with academic learning outcomes than with the alteration of learners' emotional reactions. With respect to the latter aspect, Cottle and Hart (1996) found that interactive instructions were beneficial in encouraging students' learning commitment and attitudes towards science.

In spite of the significant achievements found by many studies, interactive instruction may not always be successfully achieved, and the implementation needs to overcome many existing barriers (Hake, 1998). Possible barriers and ways to eliminate them are:

- (1) students' academic background: Meltzer and Manivannum (1996) found that the interactive instructions can be more useful when students were equipped with a certain degree of physics knowledge, and the outcomes of the interactive learning depended on the students' level of preparation in physics concepts. Mazur (1996) suggested that it is essential for students to preview the topics for the coming lesson, and that grade incentive is beneficial to encourage previewing (Hake, 1997).
- (2) students' reluctance to shift to the new teaching approach: Many students were accustomed to the education model, which emphasizes memorizing facts and formulas rather than encouraging comprehending physics concepts (Meltzer and Manivannum, 1996). At the same time, in interactive teaching, students might wonder why the lecturer does not provide the correct answer but instead asks them to search for their own answers. Students may feel that interactive instruction is difficult and time-consuming (Meltzer and Manivannum, 1996). Therefore, it is crucial that the lecturer explains the reasons for adopting the new teaching model at the beginning in order to convince the students of the need for the change (Banerjee and Vidyapati, 1997; Cottle and Hart, 1996). The literature suggested that if lecturers maintain interactive teaching continuity and dedication, then the students will take it seriously (Mazur, 1996).
- (3) required real-life problems: In order to promote students' engagement in interactive instruction, a selection of good questions is crucial (Heller and Hollabaugh, 1992; Meltzer and Manivannum, 1996). Heller and Hollabaugh (1992) found that "context-rich" problems are required for conducting a successful interactive instruction. Definitions of context-rich questions are that the context is related to the students' real life; the unknown variable is not specified, and the given information may be more than required to solve the problems (Gautreau and Novemsky, 1997; Heller and Hollabaugh, 1992; Van

Heuvelen, 1991).

(4) lecturers' hesitation: Barriers to implementing interactive instruction may not only come from the students but also from the lecturers. The lecturers may wonder if interactive instruction will force them to reduce the content coverage, as well as challenge their teaching responsibility. However, a professor at Harvard University, Mazur (1996) argued that the conventional amount of material is far beyond the students' ability to handle. Therefore, lecturers may need to release themselves from the pressure of conventional content coverage before attempting to promote interaction in their class.

The above discussion is based on the literature related to modifications to the traditional teaching approach. This research mostly dates from the past 10 years, and is focused in the United States. The suggested modifications may have been deeply influenced by the constructivist view of learning.

The next section summarises and critiques the research of the university physics education group.

2.1.5 Critiques of the university physics education research

To date, the literature of the university physics research group has pointed out the perceived problems, which include the unprepared students, the inappropriate curriculum design, and the poor learning outcomes. The literature also emphasises that the goals of university physics courses should not only be limited to the development of physics knowledge, but that learning ability and motivation should also be taken into account. Furthermore, the literature introduced a number of empirical studies regarding curriculum modification, which include modifications to the content design and teaching approach. The format for curriculum modification by the university physics education group usually followed three steps:

- (1) describing the existing problems,
- (2) trying a new teaching program, and
- (3) evaluating the outcomes of the new program.

The literature on university physics education provides the researcher with a better understanding of the background and existing problems in university physics, internationally. Meanwhile, this literature suggests ideas for modifying teaching design in order to improve learning outcomes.

However, this typical format seems to have something missing. When implementing a new teaching model, there was a lack of monitoring the learners' shift, in concept understanding, affective responses, and beliefs of learning. While evaluating the outcomes of the new program, most of the research merely evaluated the students' academic performance. Other aspects, such as affective learning outcomes and perceptions, and commitment to learning, were usually omitted by the university physics education researchers.

There may be two reasons for this omission:

Firstly, the university physics education researchers tended to adopt typical features of behaviourism, as illustrated by Duit and Treagust (1998):

.. researchers were interested primarily in discovering whether or not changes in a teaching process or in a curriculum led to changes in students' performances. Attention to why or how these changes came about was of little interest and was less common. (p.4)

Hence, the university physics education literature focuses mainly on investigating the responses (the learning outcomes) corresponding to the stimulation (the new teaching program) and neglected monitoring the process of change for the learners. There was little concern with exploring what was happening in the minds of the learners, only with their overt academic performance.

Secondly, the university physics education researchers, mainly physicists, may have held an epistemological belief dominated by positivism when designing their research (Hammer, 1996). Yielding to this belief, the university physics education researchers may have regarded evaluating learners' feelings, beliefs, and motivations as too "abstract" to count as "evidence" for the learning outcomes. They may have argued against the reliability of the tools, which evaluate learners' feelings, perceptions, and beliefs, while widely adopting the so-called standardized tools for evaluating students' academic performance. This may be

the main reason for this omission of the students' evaluation of the affective outcomes and beliefs. Meanwhile, many of these physics educators may have been devoted to being "objective" in investigating, analyzing and discussing their research results, and hence intentionally avoided personal interpretation. Therefore, most of the university physics education research articles do not search for possible explanations to link the stimulation and responses, but focused solely upon the academic outcomes.

The other concern is that the role of attitudes and emotions in the learning process was neither valued nor considered. Summarizing from the literature of the university physics education group, attitudes and emotions have been mostly accommodated as subsidiary to the cognitive achievements. Emotional consideration includes learners' intention, objectives, perceptions, and beliefs of the course and their own as learners (eg, Pintrich, Marx and Boyle, 1993; Rennie and Punch, 1991). As discussed in the previous sections, in the literature of university physics education, the investigation of students' emotional development, either progressing or deterioration, was mostly absent, in contrast to the abundant studies evaluating students' academic achievement.

Although the researchers in university physics education have gradually adopted a constructivist view of learning and are aware of the need for promoting learners' engagement in the cognitive process in physics classes, they seemed to ignore the complexity and influence of non-cognitive factors in determining students' learning. Even worse, while considering the students' cognition achievement, some of the university physics education studies not only underplayed the role of students' affective responses, but also adopted strategies which might deteriorate students' intrinsic motivations, such as an overemphasis on grades (eg, Hake, 1997; Mazur, 1996). Details of learners' affective responses in relation to learning are discussed in the literature of the general science education group in section 2.2.4.

In summary, although the university physics education researchers have provided critical information as to the trends in the research on university physics education, many of these articles over-simplified the students' learning process. The literature of university physics education researchers showed that they tended

not to consider the existing educational literature and theorising in either their research methodology or foci (eg, Hammer, 1996; Redish, 1994). This deficiency in the university physics education literature is compensated by the other research group: the general science education researchers.

The next section will discuss the literature contributed by general science education in order to obtain a better insight into the learning process.

2.2 Research in general science education

The criticism of the research in university physics education has been largely addressed by researchers in the general science education group (eg, Cziko, 1992; Hammer, 1996; Roth, 1993). The literature from the general science education group was found to be spread wider, both in location and in time, compared with that of the university physics education research. In contrast to the latter group, which focused more on practical issues, the research of the general science education group provides a theoretical framework for viewing learning, thus providing ideas for innovation in curriculum design.

The following sections describe the main themes of science education research during recent decades, followed by the implications of these studies for teaching practice. These main themes of the general science education studies are discussed in the following sub-sections:

- (1) research on alternative conceptions,
- (2) models of a conceptual development view of learning,
- (3) the role of epistemological beliefs in learning,
- (4) motivational beliefs and classroom context in relation to learning.

2.2.1 Research on alternative conceptions

In the late 1970s to 1980s, a predominant focus of science education research was on investigating students' alternative conceptions (eg, Bell, 1981; Clement, 1982;

Osborne, 1981). These are the conceptions that are strongly held and which are usually stable cognitive structures; concepts which are often different from scientists' conceptions; and concepts which may affect learners' fundamental commitment to doing and learning science (Hammer, 1996). Similarly, these conceptions were also known as "misconceptions" or "preconceptions", with each term having its own emphasis and value. The use of the term "preconception" emphasises the conceptions which existed prior to the learning process. The use of the term "misconception" implied that these existing conceptions need to be extinguished and replaced by the "correct" scientific conceptions, and that the students have failed to acquire, or have yet to acquire, the current scientific concept (Bell B., 1993; Duit and Treagust, 1998). However, the term "alternative" is used to describe a student concept so as to give it value in its own right rather than treat it as an error when compared with the scientific conceptions, and suggests that the students' ideas need to be described and explored in the students' own terms if we are concerned with learning (Bell B., 1993).

Researchers have drawn several conclusions from the alternative conception research, and these conclusions provided critical clues to a new perspective of viewing learning which impacted on traditional instructional strategies. Summarising from the general science education research (eg, Clement, 1982; Osborne and Freyberg, 1985; Osborne and Wittrock, 1985), characteristics of students' alternative conceptions and the implications to teaching practice are discussed below.

Firstly, the research on alternative conceptions showed that students tend to possess a variety of intuitive conceptions before learning in school, and that these conceptions are often different from scientists' conceptions. For example, when asking his first year university students to analyse the forces exerted on a ball moving upward in the air, Clement (1982) found that 88% of the subjects gave an upward force. Many of them noted that this upward force will gradually "die out" until the ball reached the highest position. His study implied that students possessed the conceptions of "motion needs a force", which is in conflict with Newtonian mechanics.

The second characteristic of alternative conceptions is that they are resistant to

change. This characteristic can be explained in two ways: Firstly, learners tend to see the part of the new idea which is coherent with their prior conceptions, and ignore the counterpart (Hewson and Thorley, 1989; Kuhn, 1970; Osborne and Wittrock, 1985; Roth, McRobbie, Lucas and Boutonne, 1997). Human beings have a strong tendency towards wishful thinking, ie, to see what they want or expect to see (Redish, 1996). Secondly, alternative conceptions are resistant to change as learners may misconstrue the new conceptions to avoid conflict with their existing conceptions.

Pintrich, Marx and Boyle (1993), in giving the reasons for the above explanations, noted that students' prior conceptual knowledge influences all of the information processing including perception of the cues, selective attention to these cues, encoding and comprehension of the information. This results in ignorance or misinterpretation of the concepts which the teachers attempt to teach. For example, Roth, McRobbie, Lucas and Boutonne (1997) found that students may not be aware of the key points that the teacher wants to show them in the demonstration of conservation of angular momentum. They noted that during observation, people also make decisions to distinguish between "signal" and "noise" based on their existing conceptual framework. Halloun and Hestenes (1985) studied the first year university students' initial knowledge of mechanics, and found that their initial concepts had a high correlation with their performance in university physics, regardless of instructional styles. They noted that a low score in a physics test does not mean simply that Newtonian Mechanics concepts are lacking, but rather it means that alternative and misconceptions of mechanics are firmly in place. The persistency of alternative conceptions is not only a characteristic of "normal people" but also great physicists: Newton had struggled with the impetus concept for 20 years when developing Newtonian Mechanics before he posed the Law of Inertia (Steinberg and Brown, 1990).

The third characteristic of alternative conceptions is that learners' conceptions are context-embedded. People may hold different conceptions with respect to different contexts, such as using intuitive concepts to play ice-hockey and physicists' concepts to answer a physics examination (Osborne, 1984). Thus, students may construct a new scientific concept without noticing the conflict

between the scientific concepts and their preconceptions, and so hold two opposing concepts simultaneously (Osborne and Fregberg, 1985). Conceptual change does not come easily, and is usually limited to particular contexts as conceptions are hard to transfer from one context to another (Bell and Brook, 1984; Gunstone and White, 1981; Hennessy, 1993). For example, Posner, Strike, Hewson and Gertzog (1982) found that the university students they studied, accepted the phenomenon of time variation in relativity, while still maintaining their commitment to time as invariant, based on Newtonian mechanics. These students were found to be unaware of the discrepancy. When this was pointed out to them by the researcher, the subjects used metaphors of kinetic and potential energy to explain the conflict. Stead and Osborne (1980) reported that many of the teenage students perceived light from a lamp as travelling in the night, while not travelling in the daytime.

That learners' concepts are context-embedded is supported by the ideas of "situated cognition". In a situated view of cognition, it is suggested that co-existing alternative models may be appropriate in different contexts (Hennessy, 1993). Learning then becomes a process of distinguishing when particular conceptions are appropriate rather than one of exchanging preconceptions for scientific ones (Solomon, 1983).

A final characteristic of alternative conceptions is that everyday understandings may lead the students to be more confused, rather than help them clarify their understanding of scientific concepts (Driver, *et al.*, 1994; Freyberg and Osborne, 1985). Under formal teaching, scientific conceptions may be used to explain or underpin their alternative conceptions by the students (Gilbert, Osborne and Fensham, 1982). The scientific meaning of the words is often in conflict with the everyday understanding of the situation. For example, the term of "force" is often perceived as an entity possessed by strong people or animals in contrast to the scientific conceptions of interaction within objects (Duit and Treagust, 1995). In Chinese, it is common to use the phrase of "to run out of force" to describe a person who is exhausted. Therefore, students may equate energy with force in learning physics. However, most of the students do not realize the conflict between school science and intuitive science, and regard learning physics as a way

of making their intuitive understanding more effective (Osborne, 1984). Hence, alternative conceptions may not be eliminated but may even be reinforced by university learning. For example, the impetus-like concepts appeared to increase in popularity as the age of students increased (Osborne, 1984). Therefore, learners need to be aware of the discrepancy between their intuitive conceptions and those of scientists' when learning the science conceptions (Bell B., 1993; Halloun and Hestenes, 1985).

In conclusion, there are four possibilities when a new scientific concept is introduced to students (Osborne, Bell and Gilbert, 1983):

- (1) The scientific concept is simply rejected;
- (2) The scientific concept is misconstrued, and may even reinforce the students' alternative conceptions;
- (3) The scientific concept is accepted but in isolation from the alternative conceptions, or
- (4) The scientific concept is accepted, leading to a reconstruction of the students' existing conceptions framework and the formation of a coherent view of the world.

The research on alternative conceptions suggests implications for teaching and learning practices, and these are detailed below.

Firstly, considering the future careers of the science and engineering students, four aims for teaching the university physics courses to these students are suggested:

- (1) to recognise that scientists have sensible and useful ways of investigating things, (2) to accept that most scientific concepts are intelligible and plausible, and are potentially useful to society, (3) to replace their own intuitive conceptions with the accepted scientific conceptions, and (4) to be committed to the endeavours of advancing scientific knowledge still further (Freyberg and Osborne, 1985, p.90).

A second implication of the research on alternative conceptions is that traditional instruction on its own, is an ineffective teaching approach. The research on

alternative conceptions indicates the complexity of learning and is a challenge to the traditional view of teaching and learning (Gunstone and White, 1981; Osborne, 1981). In contrast to traditional views of learning, this research states that knowledge can only be presented, but not transmitted. Learners cannot absorb knowledge as it is but they have to construct the new conceptions based on their prior conceptions. Moreover, students may construct the new conceptions differently from how the teacher attempts to teach it, ie, a mismatch may occur between the students' understanding and the teachers' teaching. Hence, it becomes essential for students to monitor and evaluate their understanding of the new conception. Traditional instruction, in which the task of teaching is limited to information transmission, the learners as passive receivers, becomes problematic for successful learning. This notion provides an explanation for the prevalent problems of poor academic performance under traditional teaching. For example, in Hake's (1997) study of the first year students' conceptions in mechanics, the 14 institutes which taught using a traditional lecturing obtained as low as 5-25% gains, when comparing the posttest with the pretest. Linder and Erickson (1989) investigated the students' concepts of sound; their subjects possessed baccalaureate degrees in physical science. They found that most of the students had constructed a notion of sound as an entity "carried" or "transferred" by air molecules, while most of them successfully gave definitions of reflection and refraction.

A third implication of the research on alternative conceptions is the critical status of learners' preconceptions/alternative conceptions in learning. Prior conceptions constitute a basis for learners to construct and understand the new conception being presented by the lecturer. Alternative conceptions can be regarded as either obstacles or facilitators for construction of new conceptions (Pintrich, Marx and Boyle, 1993). When viewing learning as a process of conceptual development from intuitive to scientific views, the persistency characteristics of existing conceptions constitute inertia to retard the construction of new conceptions (eg, Hewson and Thorley, 1989). Learning is about adjusting the relationships between a person and the world. Existing conceptions can help establish meaningful relationships between the learners and the new contexts. A well-established conceptual framework is essential for learners to interpret new and potentially

conflicting conceptions (Linder, 1993a). Meanwhile, the extinction of old ideas is not only impossible but also undesirable, since many students' everyday conceptions, such as the propagation of heat phenomena, have proven fruitful and valuable in everyday situations and provide essential links to scientific concepts (Duit and Treagust, 1998; Ferguson-Hessler and Jong, 1993; Lahtinen, Lonka and Lindblom-Ylänne, 1997; Linder, 1993a). Clement, Brown and Zietsman (1989) called these alternative conceptions "anchoring conceptions". However, it is crucial to promote the students' awareness of the incoherence between everyday life concepts and the scientific concepts, as well as their appreciation of scientific knowledge (Duit and Treagust, 1998; Linder, 1993a).

A fourth implication of the research on alternative conceptions is that the persistent characteristics of alternative conceptions broadens people's perceptions of what constitutes teaching and learning tasks in the classroom. If learning is viewed as a process of conceptual development, then what is required is that learners be active, generative and engage in a number of cognitive processes (Osborne and Wittrock, 1985). Therefore, learning tasks in the classroom involve more than merely passive receiving, such as, listening to lectures, observing demonstrations, and/or copying notes without cognitive processing. In addition, the teaching task is also different from the traditional view, which sees the teacher as devoted to providing lucid instruction while little attention is given to learning. Instead, teachers need to guide students to engage in the classroom activities, stimulate their thinking, and provide opportunities for students to evaluate the coherence of their understanding of physics concepts with their existing conceptions. Therefore, in addition to providing information, teachers need to facilitate, monitor, and intervene in their students' understanding of the new conceptions, ie, teachers act as mediators in the students' learning process.

In summary, the main purpose of the misconception/alternative conception research was not to generate a list of conceptualizations that students need to have "corrected". Rather, the above literature has provided a sensitivity about the nature of conceptualisations that students may construct, and thus broadens people's perceptions of viewing learning (Linder and Erickson, 1989).

2.2.2 Models of a conceptual development view of learning

The above discussion suggests that learning is much more profound than simply absorbing the information that teachers transmit, and thus acts as a challenge to the traditional format of teaching. This section will describe two learning models based on a conceptual development view of learning: the Generative Learning Model (Osborne and Wittrock 1983) and the Conceptual Change Model (CCM) (eg, Hewson, 1981; Posner, Strike, Hewson and Gertzog, 1982).

- ***Generative Learning Model***

Osborne and Wittrock (1983) proposed the Generative Learning Model, which described the learning process as including (1) selecting information, (2) interpreting the meaning of new conceptions, (3) evaluating the new against the existing conceptions, and (4) integrating and reconciling the new with the existing conceptions. During learning, learners generate links between the new information received by hearing and/or seeing, and their existing knowledge from memory, in order to construct the meaning of the new information. The learner may then test the constructed meanings against their memory. The status of the new idea and the existing knowledge may be gradually shifted in the learner's mind according to rational and conscious influences. This model highlighted the influence of preconceptions in the learning process, as well as the necessity of individual engagement in a series of cognitive processes in order to link, make sense, and evaluate the new concepts as a process of construction.

- ***The Conceptual Change Model***

The other model of learning science, which is called the Conceptual Change Model (CCM) was developed by Posner and his colleagues, and Hewson (eg, Hewson, 1981; Posner, Strike, Hewson and Gertzog, 1982). Whilst the model has subsequently been critiqued and revised, the initial model is worthy of consideration as it noted four conditions for concept change: intelligibility, plausibility, and fruitfulness of the new conceptions, and dissatisfaction with the existing conceptions Posner, Strike, Hewson and Gertzog (1982). Details of these four conditions, and the process of conceptual change are described below.

Firstly, the new concept must be intelligible to the learners. The learners need to search for the meaning, constructing the new concept based on their prior knowledge and experience to make sense of the teaching. Secondly, the new concept must be plausible to the learners. The learners need to examine whether the new concept is conciliatory with their prior knowledge, to determine whether the concept is reasonable. Thirdly, the new concept must be fruitful to the learners. When learners realize there is incoherence between the new concept and the prior concepts, the new concept needs to be shown to be able to (1) solve problems generated by its predecessors, and (2) be more consistent with concepts in other knowledge than the existing one. In other words, to enable a process of conceptual change the new concept needs to show that it is more “useful”, “coherent”, or “comprehensive” than the existing concepts in interpreting the phenomena. Fourthly, the learners need to feel dissatisfied with the existing concept. Observing the anomalies can challenge the learners’ faith in their existing concepts, and facilitate a conceptual change (Hewson and Thorley, 1989; Posner, Strike, Hewson and Gertzog, 1982).

The process of conceptual change does not necessarily happen with respect to these four steps in this order. Hewson and Thorley (1989) noted that intelligibility must be a first step leading to learning, and plausibility and fruitfulness determine the status of the concepts. Posner, Strike, Hewson and Gertzog (1982) noted that the learning process is unlikely to happen by directly giving up an old concept and replacing it with a new one, but by progressing gradually. Hewson and Thorley (1989) noted that conceptual change is due to a shift in status rather than a replacement of the prior concepts by the new concepts. They interpreted conceptual change as the old concept losing status and the new concept gaining status. They also argued that many researchers who adopted a new teaching sequence and claimed improvement in learning outcomes, without monitoring the process of adjusting status of concepts, failed to sufficiently investigate learning.

According to Hewson and Thorley’s (1989) notion, the learning process involves conceptual change as well as conceptual development. They view conceptual development as occurring when the learners grasp the new concept without drastically modifying their prior concepts; this process is also called assimilation

(by Posner, Strike, Hewson and Gertzog, 1982) or conceptual capture (by Hewson, 1981). On the other hand, they view conceptual change, also called accommodation (by Posner, Strike, Hewson and Gertzog, 1982), as conceptual exchange (by Hewson, 1981). Conceptual change takes place when the learners need to replace or re-organize their existing concepts in order to fit the new concept.

The distinction between assimilation and accommodation depends upon whether the prior concepts conflict with the new concepts and need drastic changes. Posner, Strike, Hewson and Gertzog (1982) studied the university students' concept of relativity and found that accommodation is unlikely to happen until some attempts at assimilation have failed.

During didactic instruction, the students are mostly passively receiving information without actively being critical of the incoming concepts. Their cognition process may be only limited to searching for the intelligibility of the new concept, ie, to understand the meaning, and mostly omits the evaluation of plausibility and fruitfulness. In this way, students are guided to recall the fact and assimilate new concepts but are unlikely to notice the defects in their existing concepts and fail to achieve accommodation. This may provide an explanation for the persistency of misconceptions and the poor outcomes of teaching by traditional instruction.

- ***Implications of the conceptual development models to the teaching task***

Based on a conceptual development view of learning, the role of the teacher as a presenter of information and clarifier of ideas is clearly not enough for helping students accommodate new conceptions (Posner, Strike, Hewson and Gertzog, 1982). They suggested that teaching strategies should focus on (1) the learners experiencing anomalies, (2) diagnosing resistance to accommodation, and (3) evaluating conceptual change in order to facilitate conceptual accommodation. Providing "discrepant event" demonstration or directly pointing out the anomalies is necessary but not sufficient for conceptual change (Roth, McRobbie, Lucas and Boutonne, 1997; Gunstone and White 1981). Teachers need to (1) diagnose the conceptions that the students are using to interpret the phenomena, and (2)

monitor the shift of the old and new conceptions in students' mind (Hewson and Thorley, 1989; Roth, McRobbie, Lucas and Boutonne, 1997).

- ***Critiques of the conceptual development models***

Although the conceptual development models discussed above appeared to be logically elegant, some researchers have argued for the inadequacy of the models. Firstly, these models did not develop the notion of conceptual ecology. Duit and Treagust (1998) defined conceptual ecology as the already-existing cognitive structural system in the learners' minds. Duit and Treagust (1995) noted that conceptual ecology consisted of the existing scientific conceptions and learners' epistemological beliefs of the nature of scientific knowledge and learning. Secondly, the conceptual development models were seen to put too much emphasis on the rational aspects of learning and neglected affective and social aspects (Hewson and Thorley, 1989; Strike and Posner, 1992). Pintrich, Marx and Boyle (1993) called the Conceptual Change Model a cold model, as it does not consider the factors of learners' motivation and beliefs. They noted that several non-rational considerations, such as learners' beliefs of how and what to learn, beliefs of themselves as learners, as well as perceptions of the goals of learning the subject, can all be critical in determining learning orientation and commitment. Meanwhile, they noted that a teaching design which takes into account the classroom context, such as teaching approach, peer's interaction, and assessment orientations, can influence students' beliefs.

2.2.3 The role of epistemological beliefs in learning

In response to the critiques of the original version of the Conceptual Change Model, Strike and Posner (1992) revised the Conceptual Change Model and noted that conceptual change is also determined by conceptual ecology, in addition to the four conditions mentioned above. The conceptual ecology is influenced by the learners' epistemological beliefs (Strike and Posner, 1992), which include learners' beliefs of the nature of science knowledge and learning science.

In this section, the discussion will focus on learners' epistemological beliefs in relation to learning approach and outcomes. Hammer (1995b) noted that students

come to the classroom not only with their prior knowledge but also with their epistemological beliefs about what to learn and how to learn; these beliefs can deeply affect the students' adoption of learning strategies as well as criteria of learning achievement. Students' epistemological beliefs of scientific knowledge and learning science are discussed below.

- ***Epistemological beliefs of scientific knowledge***

Summarising the literature, (eg, Roth and Roychoudhury, 1994; Strike and Posner, 1992) epistemological issues of the development of science include:

- (1) The relativity of truth: whether the development of scientific knowledge is to search for an eternal truth, or tentative interpretations constructed by specific societies.
- (2) The ways of developing science knowledge: whether the development process is an objective process including logical derivation (theoretical) and experimental verification (empirical), or a social/historical process through negotiating the meaning requiring people subjective judgement.
- (3) The relationship between scientific theory and everyday experience: whether the knowledge is isolated from, or dependent on, human experience.

In each of the above three issues, the first beliefs tended to be held by objectivists, and the latter tended to be held by those associated with sociocultural views of scientific knowledge. Different perspectives of the nature of science knowledge can result in different views of learning and teaching tasks. When science knowledge is presented to students as proven facts, then they will focus on memorising facts and value the empirical science methods (Roth, McRobbie, Lucas and Boutonne, 1997). On the contrary, through teaching, students may experience science as a continuous process of concept development, ie, an interpretive effort to determine the meaning of data and a process of negotiating these meanings among individuals. This group of students might focus on concepts and their variations, and value group discussion with peers when learning science (Roth and Roychoudhury, 1994). At present, most science teaching is based on an objectivist view regarding knowledge as a truth, and thus

traditional teaching has focused on direct transmission in order to allow coverage of the content (Tobin, 1990).

In addition, Hammer (1995b) and Redish, Saul and Steinberg (1998) examined university students' epistemological beliefs in the subject of physics, and categorised their responses as (1) discrete or coherent among concepts, (2) formulas/ mathematics or concepts when viewing the content, and (3) isolated or relevant to life experiences.

Hammer (1996) suggested that instructors/researchers should adopt multiple perspectives rather than focus on subject knowledge, when viewing students' misconceptions. He argued that when students fail to possess a physical concept, it may not be because they lack the requisite abilities, but may be because they hold an inappropriate belief. For example, if students construct physics concepts in isolation from others, they may see no need to link the physics concepts to life experience, and thus are unaware of the incoherence between them (Hammer, 1996). His argument is supported by Gunstone and White's (1981) study. They found that many of the first year university students fail to resolve discrepancies between predictions and observations when learning the concept of gravity. Some students even ignore the demonstration totally and use only mathematical equations when interpreting their conceptions. They implied that students can have a lot of physics knowledge without relating it to the everyday world.

The inappropriateness of epistemological beliefs provides an explanation for the persistency of alternative conceptions. Misconceptions can be generated by perceiving the world in ways different to that of a scientist, and epistemological beliefs mostly underline this (McCloskey, 1983). Strike and Posner (1992) noted that concepts are seen not only as objects of thought but as the tools of thought. Concepts consist of paradigms, which determine what questions are appropriate to ask and what to count as evidence. Therefore, what teachers regard as evidence for anomalies shown in demonstrations may be ignored by students when the students perceive scientific knowledge as independent of the real world (Gunstone and White, 1981).

Other articles have reported on the epistemological beliefs of university physics

students, and the relations between their beliefs and learning outcomes are discussed below.

Strike and Posner (1992) studied university students who had studied at least two semesters of university physics. They found that although there was no significant correlation between the students' epistemological beliefs and physics competency, students' gains in both aspects were significantly correlated. Their study found that the stronger the students believed in science knowledge as realist and empirical, the better academic performance they achieved. Halloun (1997) also found that the more consistent the students' and lecturers' perceptions were regarding learning physics, the better these students performed in university physics. Their studies may indicate many physics lecturers hold an objectivist view of knowledge, and thus rewarded students' objective beliefs through their assessment design. However, if students regard the development of scientific knowledge as inherently influenced by social, historical and cultural factors, and thus challenge the objectivity of science knowledge, they may fare better with teaching based on a sociocultural view of learning and teaching (Bell, 1999). A teaching approach which provides opportunities for students to discuss their understanding of physics concepts may help them develop their perspectives of viewing science knowledge.

Strike and Posner (1992) also noted that students might not begin to establish a stable epistemological belief of scientific knowledge until their university stage of study. University study may be a critical time for students to develop their epistemological beliefs. Their study provides an alternative teaching task, ie, to develop students' epistemological beliefs, in university physics in addition to developing students' physics knowledge.

Meanwhile, Redish, Saul and Steinberg's (1998) research found that there was a large gap between university students' and physics lecturers' perceptions of the nature of physics knowledge in terms of (1) coherence amongst concepts, (2) relevance to life experience, and (3) learning through concepts or formulas. They also found that the students' perceptions tended to deteriorate and diverged from those of their lecturers, during the learning process. The teaching style may have contributed to the deterioration of the students' beliefs. They also implied that the

students' misperceptions of the nature of physics knowledge may lead to inappropriate learning approaches, and thus result in poor academic achievement.

- ***Students' beliefs of learning***

Students' epistemological beliefs of science knowledge may interfere with their beliefs of learning science. Some studies have categorized the students' perceptions of the nature of learning as part of the students' epistemological beliefs, and investigated the relations between the beliefs and the students' learning outcomes. According to the literature (eg, Hammer, 1995b; Prosser, Walker and Millar, 1996), students' beliefs about learning include:

- (1) learning objectives as the acquisition of facts, abstracting the meaning, or constructing meanings to gain a better understanding,
- (2) learners/lecturers' role as viewing lecturers as authorised to provide the correct answer or expecting learners themselves to seek their own understanding of the concepts, and
- (3) conditions for a good learner as innate ability, hard work, strategies, personal experience, or interest etc.

An abundance of literature has reported the influence of students' beliefs on their approach to learning. For example, one research study found that most of the students taking university physics were passively waiting for their lecturer to *feed* them with correct answers rather than being critical of the instruction materials and being independent to search for their answers (eg, Hammer, 1995b; White, *et al.*, 1995). The students' learning strategy may be interpreted as the result of their commitment to the transmission view of learning, which conceptualises learning as the transfer of prefabricated knowledge that then is stored unchanged in the memory. Students' perceptions of learning also influence their conceptions of what counts as the "work" in school (Duit and Treagust, 1998). Owing to the passive view of learning, classroom discussions of alternative viewpoints and negotiated consensus are not considered as a part of "work" of the classroom, and are simply viewed as wasted time that hinders efficient progress (Baird and Mitchell, 1986). Redish, Saul and Steinberg (1998) found that during the process

of studying university physics, students' attitudes to being independent significantly deteriorated. This was attributed to the instructional style, which was dominated by didactic teaching, and which tolerated the students behaving as passive receptors in classes, hence reducing the students' learning independence. Several studies found that traditional instruction, which was firmly structured and provided few choices for the students, may have reinforced the students' dependence upon the lecturer (Trigwell and Prosser, 1991; White, *et al.*, 1995; Prosser, Walker and Millar, 1996).

Meanwhile, Dweck (1986) found that when students regard intelligence as an innate and invariant ability of an individual, they will avoid challenge. They behave with low persistence when confronted with any difficulty in learning, if they have low confidence in their ability. However, the students who believed that intelligence was malleable, ie, it can be developed through practicing, sought challenge no matter how they perceived their present ability.

Therefore, the students' beliefs of learning, including objectives, effective learning approaches and characteristics of successful learners, all have an impact on their learning strategies and commitments. Students may evaluate the quality and effectiveness of their instructors' teaching based on these beliefs, but may also gradually modify their criteria of viewing the effectiveness of teaching formats, according to learning experiences.

- ***Implications of the epistemological considerations for teaching activities***

The above discussion on epistemological considerations leads to four conclusions for teaching design:

- (1) Students' epistemological beliefs are critical to determining their foci and strategies for learning physics;
- (2) Students' epistemological beliefs can be influenced by their learning experiences with respect to different teaching designs;
- (3) Much of the existing physics curriculum design is dominated by objectivist epistemology, which seriously restricts students' perspectives of learning, and

acts as a barrier to students' commitment to social practice, such as group discussion, when learning physics, and

(4) A job for lecturers is to teach about the learning process as well as the physics.

These conclusions provide an alternative perspective to that of physics lecturers' typical views of their teaching task. Hammer (1995b) argued that physics lecturers need to broaden their teaching perspectives, so that they are not limited only to physics knowledge but also are concerned to develop the students' epistemological beliefs. To develop students' epistemological beliefs tends not be achieved through telling them the appropriate beliefs, but rather, it is through the teaching style that the students' beliefs are gradually influenced. For example, to provide an abundance of everyday life contexts in the physics class is not only to help clarify students' understanding of the corresponding theory but also to highlight the essential links between scientific knowledge and daily experience. Meanwhile, explaining daily life phenomena usually requires integrating several conceptions, which can reinforce students' commitments to valuing the coherence amongst concepts.

In addition, recent work in the philosophy of science has emphasized the role of substantive beliefs in scientific reasoning and method based on a sociocultural view of learning (Strike and Posner, 1992). Researchers have suggested that classroom activities should achieve some kind of balance between presenting information and allowing opportunities for exploration of ideas (eg, Roth, McRobbie, Lucas and Boutonne, 1997; Scott 1999). Adoption of small group discussion of concept questions in a physics class may be criticised as inefficient to cover the content from the traditional behaviourist view of learning, but it is beneficial to enhance the students' independence in learning as well as to challenge the objective nature of scientific knowledge as tentative interpretation (Hammer 1995b; Roth and Roychoudhury, 1994). Strike and Posner (1992) argued against traditional didactic teaching and noted that instruction should focus less attention on the right answer and more on the argument. To teach university physics, more emphasis should be placed on the connections between physical conceptions, experimental evidence and the conceptual ecology (Roth and Roychoudhury, 1994).

2.2.4 Motivational beliefs and Classroom context in relation to learning

Since the proposal of the Conceptual Change Model (eg, Posner, Strike, Hewson and Gertzog, 1982), several researchers have criticised the inappropriate metaphor embedded in the model, namely the process of regarding students' learning science being very much like scientists' doing science (eg, Pintrich, Marx and Boyle, 1993). The processes of developing science knowledge, which include dissatisfaction with an existing idea, searching out new intelligent, plausible, and fruitful ideas to constitute a new conceptual model, may not be a necessary part of learning science. There are two main criticisms of the model, which are discussed below.

Firstly, the Conceptual Change Model focused only on cognition, and neglected the learners' motivational considerations. Students' *motivational beliefs*, such as goals, intentions, purposes, and expectations, as well as beliefs of their ability, self-efficacy etc, can influence their cognitive engagement in academic tasks (Dweck, 1986; Pintrich and Schrauben, 1992; Pintrich, Marx and Boyle, 1993). Sections 2.2.1 and 2.2.2 have stated that the conceptual accommodation is usually the last option for the learners when assimilation appears to be seriously defected. However, accommodation is essential for the continuing educational development of learners, and thus plays a crucial role in learning (Posner, Strike, Hewson and Gertzog, 1982). Students' motivational beliefs can determine their (1) task orientation, (2) level of engagement, and (3) willingness to persist with the task (Pintrich, Marx and Boyle, 1993), and these three conditions are necessary for conceptual accommodation.

Secondly, individual learning in classrooms is not isolated, but greatly influenced by the *classroom context*, ie, peer and teacher interaction (Resnick, Levine and Teasley, 1991; Tharp and Gallimore, 1988). Students' affective responses to the classroom atmosphere, the course content and the teachers' behaviour, their preconceptions of assessment procedures, and their control of learning, etc can all influence their learning orientation and engagement, and contribute to their learning outcomes. A sociocultural perspective of motivations assumes that students' motivational beliefs are situation specific, ie, varied by different

classroom contexts, in contrast to the traditional view of regarding students' motivation as a stable personality trait (eg, Ames, 1992). The literature (eg, Malone and Lepper, 1987) suggests that a number of features of the classroom can increase students' situational interest. They are challenge, choice, novelty, fantasy, and surprise.

Details of the literature regarding the relationship between learners' motivational beliefs, classroom context, and learning are discussed as follows.

- ***Learners' motivational beliefs***

Learners' motivational beliefs include two aspects:

- (1) Their reasons for choosing to do a learning task, such as goal orientation, interest, and importance.
- (2) Their beliefs about their capacity to perform a task, such as self-efficacy, attrition, and control beliefs.

A summary of the literature (eg, Ames, 1992; Dweck and Leggett, 1988) suggests that learning goal orientation can be mainly divided into two groups: (1) intrinsic, mastery, and task-involved orientation, and (2) extrinsic, performance, and ego-involved orientation. A number of studies have shown that these two different types of goal orientation can lead to different patterns of cognitive engagement (Dweck, 1986).

Students who adopt a mastery orientation are assumed to focus on learning, comprehension, and mastering the task, while those who adopt a performance orientation are assumed to focus on obtaining a good grade or besting peers. Learners with performance goals are more likely to attribute errors and failure to a lack of ability. Therefore these students, both high and low in ability assessment, tend to promote defensive strategies when confronting challenge to avoid signifying low ability. On the other hand, students with mastery goals tend to use obstacles as a way to increase their effort, to vary their strategies and to lead to improvement in performance (Elliott and Dweck, 1988). During the learning process, learners who focus more on the errors can result in debilitation in the face

of obstacles, while learners with more focus on progress can be more likely to maintain effective strategies under difficulty/challenge (Elliott and Dweck, 1988). For example, Pintrich and his colleagues, in a series of correlational classroom studies (eg, Pintrich and Garcia, 1991), have shown that college students who adopted an intrinsic goal, focused on understanding, and were more likely to use deeper processing strategies. These strategies included elaboration and more metacognitive and self-regulatory strategies, such as planning, monitoring, and regulating. Similarly, Dweck (1985) found that the secondary students with mastery goals perform significantly better than those with performance goals, regardless of their pretest scores, in dealing with novel problems in science.

At the same time, learners with stronger confidence with certain tasks and who believe that they can control the learning outcomes with their own efforts, were found to be more likely to adopt an effective learning approach when facing difficulty (Dweck, 1975; Dweck, 1986). Abouserie (1995) found that high self-esteem is likely to be accompanied by deep level cognition, such as critical evaluation and conceptual organization.

Strike and Posner (1992) studied university students' learning attitudes and found that positive learning attitudes may facilitate their physics competency. In their study, the so-called positive learning attitudes included (1) feeling confident in one's ability to understand, (2) learning by understanding rather than by rote, and (3) valuing the course for its own sake.

- ***Classroom context and learning orientation***

While research indicates the significant links between the learners' motivation and their cognition engagement, it also suggests that the individual motivation is dependent on and situated within classroom context (eg, Blumenfeld, 1992). Classroom context includes the classroom settings, classroom interactions, and course design etc.

For example, with respect to the students' perception of workload and freedom of learning, several studies found that a perceived heavy workload encouraged students to find the "right answer" quickly, and to withdraw from challenging

tasks (Entwistle and Ramsden, 1983; Entwistle and Tait, 1990). This problem was reported for science students at university level (eg, Baird, 1986; Seymour, 1995). Baird (1986) found that the greatest concern for many university students in learning science was that the teaching pace was too fast to achieve understanding. Biggs (1987) also found that the adoption of mastery goal learning orientation by the university students in the discipline of science declined drastically, when comparing the first and the third year students.

Meanwhile, students' affective responses with respect to the classroom, such as their perceptions of enjoyment and usefulness of the course, are significantly correlated to their academic performance (Rennie and Punch, 1991). Trigwell and Prosser (1991) found that students who perceive the teaching as providing sufficient independence in learning are more likely to adopt deeper-level learning strategies such as seeking meaning to understand. Researchers also noted that students' perceptions of the learning environment can be different from the teachers', and found that the students' perceptions of the learning environment are more crucial, in leading to their learning approach, than the teachers' points of view (Fraser and Wubbels, 1995).

- ***Implications for teaching design***

Based on the literature (eg, Elliott and Dweck, 1988; Ames, 1992), suggestions for the classroom context in order to encourage the adoption of mastery goal orientations, are described below.

Firstly, the tasks need to be more meaningful, challenging, and authentic, ie, to be more relevant to life. Conducting group discussions on the physics concepts of life phenomena with longer periods of time for completion, is suggested to facilitate deep cognitive engagement and conceptual accommodation (Pintrich, Marx and Boyle, 1993). The literature also suggests that continuous success with easy tasks is ineffective in producing stable confidence and persistence (Dweck, 1975), while appropriately challenged tasks are often the ones that are best for utilizing and increasing the students' abilities (Dweck, 1986).

Secondly, teachers need to reduce their authority in teaching, and enhance the

students' belief in control over their own learning. Reducing the teachers' authority and providing choice of learning can encourage students' intrinsic motivation. From this point of view, setting time constraints, highlighting the time pressures, and stressing task completion may guide students towards focusing on completion rather than on comprehension, due to the fear of ineffectiveness. Meanwhile, teachers need to guide students to attribute their failures to insufficient effort or ineffective strategy, rather than to lack of ability, in order to enhance their persistence in the face of failure (Dweck, 1975).

Thirdly, evaluation procedures should place an emphasis on the students' reasoning processes rather than on recall of the "correct answer". Traditional instruction that focuses on clear and definite answers, stresses the costs of being wrong, and encourages competition with peers, may enforce students to abandon mastery learning goals and adopt surface cognitive processes instead.

Finally, based on the learners' motivational considerations, a number of studies provided suggestions for teaching tasks, including: (1) maintaining a supportive classroom atmosphere to promote learning motivations (Wubbels and Brekelmans 1997), (2) communicating high expectations to reinforce the students' confidence and encourage high achievement (Biggs and Moore, 1993), and (3) providing instant feedback on the students' achievements to promote their awareness of learning (Gibbs, 1995) and enhance their affective responses towards the course (Rennie and Punch, 1991).

The above suggestions are apparently discrepant with the conventional classroom context in university physics, where the teaching pace and workload are usually far beyond the students' ability and time for learning. The teaching content tends to be isolated from the students' life experience. The classroom is dominated by a didactic way of teaching providing little opportunity for students to evaluate their understanding of physics concepts, and little feedback for students' learning. And, in addition, the assessment seldom asks for reasoning processes, but emphasises obtaining the right answer (see sections 2.1.3 and 2.1.4). All of these features can do nothing but foster the students' performance goal orientation, encourage them to adopt a surface cognitive process and hinder their conceptual development. Therefore, teachers may have to change not only their general instructional

strategies, as suggested by the conceptual development models, but also modify their tasks, authority, and evaluation structures to encourage their students to shift from performance goal to mastery goal orientation.

The next section will summarise the assertions of the literature in the general science education group.

2.2.5 Summary of the literature of general science education

The main ideas provided by the research in science education are summarised below.

Firstly, the research on alternative conceptions has indicated the role of learners' existing conceptions and the complexity of learning. Their findings have resulted in a major challenge to the traditional didactic way of teaching.

Secondly, the learning process can be influenced by cognitive and emotional factors.

With respect to cognitive factors, the Conceptual Change Model provides a rational learning model and suggests four conditions for achieving learning. The related literature indicates that learning is a process of conceptual development rather than a process of simply "piling up" the knowledge in the learners' memory. Thus this model highlights the necessity of individual learner cognitive engagement in learning.

With respect to emotional factors, the learners' epistemological commitment and motivational beliefs are found to play a crucial role in guiding learners' cognitive engagement and learning orientation. Learners' epistemological commitment and motivational beliefs are also found to be deeply influenced by the classroom context.

In short, learning is determined both by cognitive and emotional factors, and the learning process involves both individual cognitive processing as well as social practice.

Section 2.2 has described four main themes of the research in the general science

education group in recent years, which has provided a wider scope to the researcher when viewing teaching and learning. The next section will summarise the main views of learning reflecting the above assertions.

2.3 The main views of learning

The literature discussed above (in sections 2.1 and 2.2) indicates a variety of models of viewing learning and their implications for teaching designs. In relation to this thesis, the educational literature on learning can be categorised into three groups: (1) behaviourist views, (2) personal constructivist views, and (3) sociocultural views of learning (Duit and Treagust, 1995). This section will summarise each learning perspective, including its perspectives on the nature of (1) science knowledge, (2) the learning process, and (3) teaching tasks. These three parts are closely linked to each other, ie, physics lecturer perspectives on the nature of science knowledge determines their views of learning and thus influences their commitment to the teaching tasks in the classroom (Guo, 1992; Roth and Roychoudhury, 1994).

The three learning theories will be summarised in the following sections.

2.3.1 Behaviourist views of learning

Lecturers of university physics tend not to have a pedagogical background, and thus tend to teach this subject based on their prior learning experiences, which are usually from a traditional perspective (Elton, 1997). This so-called traditional perspective is dominated by the objectivist epistemological view of the nature and development of scientific knowledge (Redish, 1994). In keeping with this commitment, many physics lecturers hold a transmission view of learning, and thus widely adopt a didactic format of instruction (Roth and Roychoudhury, 1994). This perspective has much in common with a behaviourist view of learning, which is discussed below.

With respect to the objective epistemology of viewing scientific knowledge, physics lecturers tend to perceive scientific knowledge, conceptions and theories as holding the truth value of proposition, which can be tested empirically

(controlled experiment) and rationally (mathematical verification) in the natural world (Roth and Roychoudhury, 1994). Such a view sees that there is an eternal reality existing in nature, and eternal reality can be objectively “discovered” by scientists, and people can make objective and unconditional truth statements (Costa, Hughes and Pinch, 1998). The so-called scientific methods allow us to transcend the subjective limitations of individuals to test and to ascertain the absolute truths (Roth and Roychoudhury, 1994). Therefore, scientific knowledge is regarded as independent of personal experiences and subjective judgement, as well as of historical, cultural and social considerations.

From an objectivist perspective, scientific knowledge is regarded as an entity, which is transmittable. The objective perspective of scientific knowledge is found to contribute to the behaviourist view of learning. Behaviourists view the student’s mind as a container of knowledge, and the brain is regarded as being able to absorb and store the facts in the mind (Roth and Roychoudhury, 1994). The brain requires exercise in order to enhance its capability. Meanwhile, behaviourists emphasis reinforcement and learning in small steps, in which increasingly complex skills and patterns of behaviour can be built up through carefully designed instruction based on learning hierarchies (White, 1973).

With respect to the transmitted view of learning, learners are regarded as ignorant, and their conceptions are constructed by their instructors. Students’ learning tasks are limited to “proving” the science knowledge objectively and to accumulate these facts in their memory (Duit and Treagust, 1998). Thus students focus on completion rather than comprehension (Roth and Roychoudhury, 1994). Meanwhile, the objective and the transmitted perspectives of scientific knowledge and learning result in the dichotomy of learning outcomes: the student either knows or does not know the knowledge taught by instructors (Redish, 1994).

Behaviourist views involve a simplification of the learning process, learning tasks, as well as the evaluation of learning outcomes, compared to the constructivist (see section 2.3.2) and sociocultural views (see section 2.3.3) of learning and teaching.

Behaviourist philosophy asserts that one can formulate all of one’s theories only in terms of direct observations and measurements (Gardner, 1987). This is in

conflict with the cognitive scholars, who focus on how people think in terms of mental models, and these cannot be directly observed.

The tendency towards behaviourism of many physicists was also reflected from the format of much of the research in university physics education, which were designed by physicists (eg, Gautreau and Novemsky, 1997; Heller, Keith and Anderson, 1992). The physicist educators' behaviourist underpinning of their research was critiqued in section 2.1.5.

Due to the objectivist views of scientific knowledge and behaviourist views of learning, the traditional teaching format has focused on the direct transmission of these "facts". To make the transmission effective, whole-class non-interactive activities are mostly adopted because they allow the coverage of much content (Roth and Roychoudhury, 1994), and an explicit and clear presentation. In a traditional classroom, the instructor plays a central role, and his/her teaching task is limited to presenting information, including interpreting concepts, giving mathematical verifications, and doing demonstrations (Roth and Roychoudhury, 1994). Correspondingly, the students' main task in the classroom is seen as collecting information, such as copying notes, and observing demonstrations, rather than actively engaging in individual cognitive processes and/or social practice.

Yielding to the objectivist epistemological view of scientific knowledge, the curricula of university physics mainly aim to "prove" and to "transmit" scientific knowledge. Therefore, the curricula usually consist of two parts:

- (1) A didactic format of lecturing which allows for the "mathematical verification" as well as "transmission" of science knowledge into learners' brains, and
- (2) Recipe-like laboratory exercises to provide empirical evidence to "prove" scientific theories, and to reinforce students' memorisation of the scientific knowledge taught in the lecture (Roth and Roychoudhury, 1994).

This type of curriculum design has endorsed the objectivity of scientific knowledge (Roth and Roychoudhury, 1994), and thus enhanced the reasons for adopting the traditional curriculum design and retarding teaching innovations.

The foci of the conventional classroom in university physics are limited to the teaching content and the instructors, but learners and their learning processes are mostly ignored. While teaching, most of the physics lecturers focus mainly on subject content and ignore other considerations such as teaching approach, students' learning orientations, students' existing conceptual ecology, as well as the influence of classroom context etc (Redish, 1994).

In short, traditional perspectives perceive that what is taught can be directly translated to what is learnt, and this perception promotes the instructors' devotion to didactic teaching approaches.

The above perspectives which tend to be held by the majority of physics lecturers is certainly seriously discrepant with that of the general science education researchers in recent decades. In comparison with the physics lecturers' points of view, two learning models have been posed in recent decades by science education researchers. These two models are the personal constructivist and the sociocultural views of learning, and they are summarised respectively in the following two sections.

2.3.2 Personal constructivist views of learning

Behaviourist views of learning were challenged by Piaget's ideas of intellectual development in the late 1960s. However, research into students' learning into science did not shift to a cognitive perspective until the middle of the 1970s (Duit and Treagust, 1998). At the same time, various disciplines relevant to science education, such as philosophy of science, sociology, cognitive psychology, and pedagogy encompassed the notions of constructivism in the late 1970s (Duit and Treagust, 1998). The personal constructivist view of learning in science was developed in the 1980s.

Piaget viewed the purpose of intellectual growth as coming to know reality more objectively, ie, intellectual development is viewed as increasing decentration from subjectivity toward objectivity (Piaget, 1970). This was a developmental view of learning. He did not believe that we could apprehend reality through direct experience, as behaviourists do. He suggested that, by stages of operations, we

have acquire abstract, logico-mathematical reasoning capacities that allow us to detach ourselves from the object world and reason about it logically (O'Loughlin, 1992). This cognitive development regards reasoning as content-free, value-free, and purely logical. Meanwhile, he emphasised that knowledge is constructed by the individual while interacting with the environment and trying to make sense of it. The meanings of the knowledge held by an individual is not acquired from the world outside, but by construction from internal representations (Osborne and Wittrock, 1985).

The emphases of individual construction through cognitive processes can be regarded as the root of constructivism (O'Loughlin, 1992). However, the absence of interest in context and learners' pre-existing conceptions indicated the difference between the Piaget's and the personal constructivist views of learning (O'Loughlin, 1992).

Differing from Piaget's argument, personal constructivists claimed that all we know about reality is our tentative construction, although the reality outside the individual is not necessarily denied (Duit and Treagust, 1998). Personal constructivists accept the ontological reality of the external world, but suggest that human minds do not have direct access to it (Geelan, 1997; Guo, 1992). In other words, constructivists perceive scientific knowledge as a human constructed understanding of the world, rather than a direct reflection of the real world. Therefore, the development of scientific knowledge is determined by social and historical transitions. Accordingly, learning is not viewed as transferring of knowledge, but the learner constructing his or her understanding of a new concept, using incoming stimuli and existing knowledge. Throughout the 1980s and early 1990s, the mainstream of constructivism in science education emphasised the individual cognitive process and neglected the social aspects. Hence it was called personal constructivism.

The central theme of the personal constructivist view of learning is that the preconceptions held by individuals guide their understanding of new ideas (Tobin, 1993). Details of learners' preconceptions are summarised below.

Firstly, since the middle of the 1970s, an abundance of studies in science

education revealed the existence of learners' preconceptions before learning (eg, Halloun and Hestenes, 1985). These preconceptions appeared to be diversified amongst different groups of learners, as well as being discrepant from scientists' conceptions. Learners' preconceptions are also found to be held strongly and to be resistant to change. Secondly, learning science involved learners interpreting the meaning of the new knowledge based on their preconceptions (Osborne and Freyberg, 1985). Learners' preconceptions are influenced by their prior experiences, which are diverse amongst individuals. Therefore, students may construct their conceptions differently among peers as well as in discrepancy with the conceptions their instructors intended them to construct. Thirdly, for most of their learning, students tend to construct the meaning of new conceptions in ways that are in accordance with their preconceptions (assimilation), and avoid drastic modification of their prior conception structure (accommodation). Conceptual accommodation is unlikely to take place unless learners confront a series of difficulties in attempting assimilation (Posner, Strike, Hewson, and Gertzog, 1982). Therefore, learners need to exert effort to modify their preconceptions while comprehending new scientific conceptions (Posner, Strike, Hewson and Gertzog, 1982). However, some alternative conceptions, which are useful in everyday life contexts, do not necessarily need to be expelled, as long as the learners are aware of the inconsistency between their everyday life concepts and the scientific concepts (Duit and Treagust, 1998; Linder, 1993a).

The "Conceptual Change Model" (see section 2.2.2) became a key notion in the 1980s to the early 1990s. This model posed four conditions to achieve conceptual change, ie, dissatisfaction with the existing conceptions, intelligibility, plausibility, and fruitfulness of the new conceptions. The learning process is regarded as containing conceptual development and conceptual exchange, while the boundary between the two is not clearly distinguished.

Based on the above assertions of the personal constructivist views of scientific knowledge and learning, the implications of this learning model to teaching are discussed below.

Firstly, personal constructivism has promoted a focus on the learners in classroom activities. As described by Fosnot (1989):

Learning needs to be conceived of as something a learner does, not as something that is done to a learner (p.5).

Knowledge can only be presented rather than be transmitted by physics lecturers. A physics lecturer's role is not only to present scientific ideas, but also to be a guide to stimulate learning motivation and promote cognitive engagement, and to challenge or intervene in students' preconceptions to assist them in constructing new conceptions.

A second implication of a personal constructivist view of learning is the teaching strategies. Summarising a number of constructivist studies, Scott, Asoko and Driver (1991, p.326-327) suggested the following teaching strategies for conceptual development:

- be aware of students' ideas and understandings relating to the topic under consideration;
- be aware of likely conceptual pathways for that topic;
- be sensitive to the students' progress in learning;
- be able to generate learning tasks to support and encourage that progress in learning;
- be sufficiently confident in his/her own understanding of the subject topic to be able to appreciate, and respond to, differing points of view;
- be able to organise and manage a classroom which will allow for all of this to happen.

In summary, personal constructivism has revealed the complexity of the learning process, and highlighted the critical role of learners' cognitive engagements in their learning process. Regarding the learning and teaching of science, what students have experienced and perceived of the world, and how they interpret new ideas are just, if not more important than what teachers perceive and attempt to teach. The focus has shifted from what the teacher has taught to what the student had learnt. The two are not necessarily the same.

2.3.3 Sociocultural views of learning

The early constructivist learning model, which concentrated on the individual cognitive processing of knowledge, has been critiqued (Bell, 1999; O'Loughlin, 1992):

- (1) Personal constructivism ignores the social, cultural and historical influence on students when learning science. While students learn in school, the classroom context may influence their learning attitudes and adopted strategies, and thus influence their learning outcomes. Meanwhile, the social interactions and learning practice in the classroom are regarded as essential for students to be familiar with the culture and the “way of seeing”, which has been developed within the community of science (O'Loughlin, 1992; Scott, Asoko and Driver, 1991). Learning science involves being initiated into scientific ways of knowing (Driver, *et al.*, 1994).
- (2) The model does not consider the affective, motivational and intentional aspects of thinking and learning. Learners' emotional factors may not only influence the quantity of learning commitment, but also influence their learning attitudes and strategies, eg, persistency when confronting difficulties in learning, trying alternative strategies when solving novel questions (Dweck, 1986; Pintrich, Marx and Boyle, 1993).
- (3) The influence of the learners' epistemological beliefs in the learning engagement and outcomes is not addressed. The students' epistemological beliefs of physics knowledge and learning physics can deeply affect their focus and strategies of learning. Inappropriate beliefs of what and how to learn can be an origin for decreasing conceptual development (Hammer, 1995b; Prosser, Walker and Millar, 1996).

Following these criticisms, a sociocultural view of learning has been developed by researchers since the 1990s (eg, Perkins, 1993; Salomon and Perkins, 1998; Wertsch, 1991).

In contrast to the personal constructivist view, the sociocultural perspective regards knowledge as distributed and shared rather than as being the property of

individuals (Duit and Treagust, 1998). Science knowledge is not “facts” that are discovered by people, but is the result of selective observation, and a continuing argument over the interpretation of those observations (Costa, Hughes and Pinch, 1998). Many of the current “truths” in science were hotly debated at one time, and the role of social commitments in these controversies is much more significant than is indicated by a traditional view (Costa, Hughes and Pinch, 1998). Knowledge is distributed among the members of a specific community, and the meaning of that knowledge is negotiated and shared by this community as well as possessed by individuals. Therefore, knowledge is something between the individual and the specific society (Bell, 1999; Duit and Treagust, 1998). Gergen (1995) suggested that knowledge does not arise or reside within the natural world (as with the behaviourist view) or within cognising individuals (as with the personal constructivist view), but within societies. It is important for students to appreciate that scientific knowledge is both symbolic in nature and also socially negotiated (Driver, *et al.*, 1994).

The process of constructing meaning is always embedded in a particular social context, although an individual has to construct their own meaning of a new idea (Duit and Treagust, 1998). Bell and Gilbert (1996, p.50) summarised one social constructivist view of learning as:

- Knowledge is constructed by people.
- The construction and reconstruction of knowledge is both personal and social.
- Personal construction of knowledge is socially mediated. Social construction of knowledge is personally mediated.
- Socially constructed knowledge is both the context for and the outcome of human social interaction. The social context is an integral part of the learning activity.
- Social interaction with others is a part of personal and social construction and reconstruction of knowledge.

At the same time, the sociocultural perspectives of learning are evident in the following three views: (1) situated activity, (2) mediated action, and (3) distributed cognition (Bell, 1999).

Firstly, when viewing learning as a situated activity, learning is regarded as a way to increase the learners' access to participation in roles of expert performance (Hanks, 1991). Learning means to adopt different cultures as well as to be able to use a new language (Lemke, 1990; Hennessy, 1993). "Cognitive apprenticeship" is often seen as a good method for introducing the learner, as the expert guides the apprentice (novice) to move into a new culture, to be able to use the sign system correctly, and to think effectively (Driver, *et al.*, 1994). Cooperative learning is thus regarded as an effective strategy. Thus, learning can be viewed as a process of individual participation in a social practice, awareness of a set of cultural conventions and specialised local knowledge, rituals, practices, and vocabulary are developed (Hennessy, 1993). This view is different from the behaviourist and the personal constructivist perspectives, which view learning as a process of acquisition or internalisation of knowledge in an individual mind.

Secondly, learning can be viewed as mediated action (Salomon and Perkins, 1998; Wertsch, 1991). Human action and mental functioning are mediated by tools (eg, computers), signs (eg, mathematical symbols or languages), and the social context. For example, language is an essential tool involved in the human thinking process. Meanwhile, social interactions in the classroom can facilitate individual construction through explicit guidance, modeling, encouragement, mirroring, and feedback (Salomon and Perkins, 1998). It becomes unreasonable to separate individual student's cognition and motivation from the classroom context in which the learning is taking place (Bell, 1999). Hence, while learning, the cognitive agent and the means (tools, signs, and the classroom context) are inseparable.

Thirdly, learning can be viewed as distributed cognition. While learning, the social and artifactual surrounds, such as the classroom setting, and language, are not only sources of input to thinking but also vehicles of thought (Salomon, 1993). The cognition process does not occur inside a learner's head, but rather, learning takes place in a system comprising of an individual, peers, teachers and

the artifactual tools. Linder (1993a) noted that learning means to establish a meaningful relationship between the individual and the world, while the personal constructivist view of learning sees it as occurring inside a person's brain.

The above discussion of sociocultural views of learning can inform teaching in several areas, which are discussed below.

Firstly, sociocultural views of learning focus on the "mind" rather than the "brain", and on "human action" rather than "behaviour" (Bell, 1999). The sociocultural view of learning addresses the integration of cognition, affect and conation, while the personal constructivist approach focuses only on individual cognition. "Mind" implies socialised and mediated properties (Wertsch, 1991). Even when a learner is thinking alone, the tools and means needed for thinking (eg, language, symbols) are socially established. Individual cognition cannot be in isolation from social interaction, and learning is viewed as social practice rather than individual cognition.

Secondly, sociocultural perspectives also highlight the consideration of students and teachers' epistemological beliefs in relation to learning science. These beliefs include their perceptions of science content, the nature of scientific knowledge, the aims of science instruction, the purposes of particular teaching events, and the nature of the learning process (Duit and Treagust, 1998). Through the teaching and assessment design, as well as the interactions in the classroom, teachers and students share and negotiate the criteria of what and how to learn; what activities are effective in learning and are expected to occur in the classroom, what counts as achievement, what kind of assessment design is acceptable etc. For example, when the demonstrations shown in class appear to be irrelevant to their grade, the students may isolate physics knowledge away from their everyday experiences (Roth, McRobbie, Lucas and Boutonne, 1997). Meanwhile, while students perceive their learning task in the classroom as limited to passively receiving information, they may regard small group discussions as a waste of time.

Thirdly, based on the sociocultural views of learning, the use and meaning of a language become critical in learning science. Learning science means to learn a different language (Lemke, 1990). The use and meaning of language are

socialised. Roth, McRobbie, Lucas and Boutonne (1997) noted that people have to engage in and develop practices together to negotiate their understanding, and repair discursive trouble (misunderstandings and errors). Group discussions of conceptual questions are thus suggested for in the physics classroom to allow students to appreciate the role of language in learning physics (Roth, 1995). The classroom becomes a place for all participants to engage in the developing social practice of being acquainted with the language shared by the science community. Finally, sociocultural views of learning regard conceptions as context-embedded. Different contexts result in different conceptualisations. For example, the concept of atmospheric pressure is different from that of a box of gas. Light can be interpreted as either wave (when dealing with the colors of soap bubbles) or particle (when interpreting the photoelectric effect), or both wave and particle (when explaining the light reflection of a mirror). The conditions of the context determine the appropriateness of the conceptions. For example, Newtonian mechanics is valid in daily life but not in the atomic world. Thus, empirical evidence is replaced by viability of knowledge, ie, coherence, usefulness and intelligibility (Roth and Roychoudhury, 1994). Physics lecturers may need to be aware that this perspective is very different from the conventional textbooks of university physics, where physics conceptions and terminology are often introduced without providing a corresponding context.

In summary, sociocultural views of learning provide wider perspectives of learning. Learning does not merely happen inside an individual learner's brain, but rather in the classroom context, which includes activities in the classroom, the interactions amongst peers and between students and teachers, the discourse in the classroom, etc, all of which can affect the students' learning. Learning at university requires participation in social practice, through the teacher's guidance and peer interactions to adopt from the culture of everyday life to that of a science community.

The above sections discussed the different perspectives of the three main learning theories (ie, behaviourist, personal constructivist, and sociocultural views) as well as their implications for teaching. A summary of the literature is given as follows.

2.3.4 Summary of the literature

The above discussions have introduced the literature of both the university physics education group and the general science education group. Their foci and contributions are now summarised as follows:

The general science education researchers have put much emphasis on areas that were usually absent in the university physics education research. Much of the literature of the general science education group monitored the learning process in either cognitive and/or emotional aspects, and some of the general science education studies took into account socio-cultural factors.

The general science education research mainly included the following three components:

- (1) awareness of the complexity of the learning process,
- (2) monitoring learning process to formulate learning models, and
- (3) providing a wider perspective on learning, including cognitive, emotional, and social aspects.

On the other hand, the university physics education group mainly adopted the empirical research design, searching for the causal correlational links between instruction styles and the students' academic achievements. However, several considerations are seriously ignored by this group of researchers. The considerations ignored are:

- (1) the lack of monitoring of the transition occurring in the intervention teaching program in both students' emotional reactions as well as the cognitive outcomes,
- (2) the absence of any attempt to search for possible reasons to interpret the links between instruction styles and learning achievements,
- (3) insufficient consideration, if not total absence, of learning theory, when designing the research and analysing the data. Therefore, this group of researchers does not attempt to contribute to theorising on students' learning.

To conclude, within the context of university physics education, the literature has found that:

- (1) Numerous studies have focused on investigating the students' development of their understanding of physics concepts. These studies either adopted quantitative evaluation by standardised tests (mainly multiple choice questions) providing macroscopic knowledge, or qualitatively explored the students' understanding by interview or open questions, providing a microscopic view of the students' achievement in physics. These studies have revealed the complexity of learning physics.
- (2) A few studies have investigated the students' learning attitudes, perceptions, and/or beliefs while taking university physics courses. Some of these have compared the students' emotional factors with their academic performance, and highlighted the emotional considerations of teaching physics.
- (3) The majority of studies on university physics were underpinned by a traditional view of teaching, and most of them identified the problems of the low achievement in constructing scientific concepts. A few reported on the passive learning attitudes and/or superficial perceptions/beliefs of physics knowledge and learning physics. In other words, the literature has revealed the weaknesses of the traditional teaching design.
- (4) There is a lack of studies in Asian countries with respect to university physics education.
- (5) In attempting to improve the learning outcomes, several studies have tried to modify the traditional teaching design and evaluate the outcomes. These studies were found to limit their investigations to evaluating the students' academic achievement, mainly by standardised tests. Although these studies have mostly obtained positive results, they did not provide enough information to explain the outcomes.

The literature seems to provide insufficient knowledge of the ways of improving the learning outcomes through modifying the traditional teaching design in university physics, especially considering the learners' motivation and social

aspects. Meanwhile, the findings in western countries may not be applicable to the situation in Asian countries such as Taiwan. This deficiency indicates the need for this research.

The thesis and research questions will be discussed in the next section.

2.4 The thesis and research questions

Based on the literature, the thesis of this research is that learning physics is both a social practice as well as an individual cognitive process. Learning physics is much more complex than simply transferring knowledge from the lecturers' brain to the students', and "piling it up" in their memory. Meanwhile, learning physics is not simply a pure cognitive activity, but rather, it involves social participation and practice in order to be acquainted with the culture of the science community. A combination of constructivist and sociocultural views of learning is more fruitful than the transmission view in order to describe university students' learning in physics. The learners' cognitive engagement, emotional influence, and social interactions may all influence their learning outcomes.

Based on the thesis, the questions for this research are discussed below.

- (1) What is the initial situation of the incoming students? The students' initial situation includes learning attitudes and expectations towards the course and physics background.
- (2) What are the learning outcomes of traditional teaching in university physics courses? The learning outcomes include the students' academic achievement, learning attitudes and perceptions of the course, and the participation/interaction in the classroom. Both the students' and physics lecturers' opinions are important.
- (3) What is an appropriate design for an intervention teaching program modifying the traditional teaching design?
- (4) What are the learning outcomes of the intervention teaching in comparison with the traditional teaching? Any evaluation of the outcomes would include

the students' academic achievement, affective responses towards the course, learning commitments and approaches, and participation/interaction in the physics class. The roles of cognitive engagement and social practice in the physics classroom in relation to their learning outcomes are also important.

Chapter 3

Research methodology

In this chapter, details of the research design, which include research tasks, research phases, adopted methods, and the design of the research tools etc, are presented. The characteristics of education research methodology, based on the literature, are also discussed.

The information is presented under five headings:

- (1) the characteristics of educational research,
- (2) an overview of this research,
- (3) research design (part I): Understanding the existing situation,
- (4) research design (part II): Evaluation of the intervention teaching, and
- (5) summary.

3.1 The characteristics of educational research

The literature provided suggestions about educational research design, which have developed the researcher's perspectives of viewing education research. Based on this literature, the characteristics of education research are discussed in five sections as follows:

- (1) categories of education research,
- (2) the differences between physics research and education research,
- (3) characteristics of quantitative and qualitative research methods,
- (4) interviews, and

(5) questionnaire survey.

3.1.1 Categories of education research

Best and Kahn (1993) categorized educational research into four groups, which include:

- (1) historical research: The purpose is mainly to understand what was the past, and thus, anticipate the future.
- (2) quantitative descriptive research: Using quantitative methods to describe what is the existing situation, in an attempt to discover relationships between variables. Statistical analysis is usually used to describe the results.
- (3) qualitative descriptive research: Using systematic procedures to discover what are the non-quantifiable relationships between existing variables.
- (4) experimental research: Deliberate control and manipulation of certain variables to describe what will be the variable relationships. The experimental validity is based on the randomization and control treatment of equivalent groups, and the research is categorized into three groups in the order of their validity: true experimental, quasi-experimental, and pre-experimental design.

An education study may be a combination of these types. The research for this thesis consisted of both quantitative and qualitative descriptive research methods when searching for better understanding of the existing situations, and quasi-experimental research when evaluating the outcomes of the intervention program.

3.1.2 Differences between physics research and education research

Several science education researchers (eg, Cziko, 1989; Hammer, 1996) noted the differences between physics research and education research. Their suggestions broaden the physicists' perspectives of viewing education research, which include the differences of the research purposes and their epistemological commitments.

Considering the research purposes, Hammer (1996) suggested a view of current physics education research as providing perspectives to expand and refine

instructors' perceptions and judgement rather than providing definitive principles or proven methods. He argued that based on experiences with physics research, physics educators tend to assume that research should provide unambiguous and reliable principles and methods. Physicists also tend to search for valid results, which are sufficiently precise so as not to allow subjective interpretation and judgement (Hammer, 1996). Education research should focus on providing descriptions and interpretations of educational phenomena to provide findings that can be used to improve our understanding of learning (Cziko, 1989; Roth, 1993). Cziko (1989) argued against making certain predictions and devising "cookbook" solutions. A physicist and education researcher, Redish (1994), noted that

ideas from education research cannot provide us with hard and fast rules for what to do... . But I have found that they help me to organize my thinking about my students and to refocus my attention (p.796).

With respect to the epistemological disparities, Cronbach and Snow (1977) concluded that comprehensive and definitive experiments in social science are not possible and that the most we can hope to achieve in educational research is not prediction and control but rather only temporary understanding. Unlike science experiments, student variables such as intelligence, motivation, cognitive style, socioeconomic status, and background knowledge are extremely difficult to measure, and impossible to control and predict (Cziko, 1989). The uncontrollability and unpredictability of human behaviour have created barriers to the use of "scientific methods" in carrying out education research. Meanwhile, the complexity of human behaviour explains why educational research has not received the consensus that research in the physical sciences has achieved (Cziko, 1989). The epistemological differences between the study of human cognition and the study of the physical world will preclude a physics-like formalism in education (Hammer, 1996). Cziko (1989) suggested that education researchers should place more emphasis on the micro level of individual behaviours, feelings and cognitive processes, in order to lead to an appreciation of the complexity of education and provide ideas for innovations.

In summary, the literature pointed out that the characteristics of education research, dealing with human's thinking and behaviour, are so profound that the scientific method, which includes control and prediction, is not appropriate to

education research. Thus, the goals of current education research focus on providing better understanding in learning rather than establishing formulas for instructors to follow.

3.1.3 The characteristics of quantitative and qualitative research methods

Based on the characteristics of education research mentioned in the above section, qualitative descriptive methods have become an acceptable way of investigating students' learning, perceptions, and attitudes. In fact, the status of the quantitative methodology has been challenged by the qualitative methodology over the last decade.

This research consisted of three types of data collecting techniques, which were (1) questionnaire survey, (2) interview, and (3) achievement tests. The data collected from each research technique may have needed to be analyzed by both quantitative methods and qualitative methods. Analysis methods are adopted with respect to the types of the questions, rather than the types of data collecting techniques. For example, results of closed questions are more suitable for quantitative analysis, while qualitative analysis is good for analyzing responses to open-ended questions.

In this research, the student surveys and achievement tests were mostly in closed-form, thus, the quantitative analysis methods were applied to them. Qualitative analysis methods were utilized in analyzing the interview data, both from the students and the lecturers, as well as the open-ended questions of surveys. Best and Kahn (1993) noted that

an open-form question is likely to produce greater in-depth response; however distilling the essence of the reaction is difficult. The closed-form question is easier to record and analyze, but may yield more superficial information (p.252).

The next two sections will discuss the views expressed in the literature with respect to the two main techniques adopted in this research: interview and survey.

The literature provided sufficient information concerning the adoption of different

research techniques, which include the strengths, the weaknesses and suggestions for each type of research design. These researchers' opinions are summarized with respect to the two areas of interview and questionnaire survey.

3.1.4 Interviews

Moser and Kalton (1971) described the interview as a conversation between interviewer and respondent with the purpose of eliciting certain information from the respondent, but they also noted that the attainment of a successful interview is much more complex than a straightforward conversation. An interview is more than just an interesting conversation (Bell J., 1993). Patton (1990) pointed out that

the purpose of interview is not to put things in someone's mind but to access the perspective of the person being interviewed (p.278).

Cohen (1976) noted that

like fishing, interviewing is an activity requiring careful preparation, much patience, and considerable practice if the eventual reward is to be a worthwhile catch (p.82).

The above statements have highlighted the demand of research skills in conducting interviews.

- ***Categories of interviews***

Patton (1990) categorized the structure of interview, from completely open-ended to very formal, into four groups: (1) informal conversational interview, (2) interview guide approach, (3) standardized open-ended interview, and (4) closed, fixed responses interview. The former are more flexible, while the latter are more structured.

The strengths of the more flexible interview format include increasing the salience and relevance of the questions, and matching to individual circumstances, while the weaknesses are that the data may lack system and cause difficulty in data analysis (Patton, 1990). On the other hand, in a well-structured interview, the data is simple and easily compared and aggregated, but some questions may be perceived as impersonal, and thus can distort what respondents really mean (Bell

J., 1993; Patton, 1990).

In this research, the interviews all adopted the interview guide approach format, ie, topics and issues to be covered were specified in advance, in outline form, and the interviewer was able to apply different sequences and wordings of questions to each interviewee (Patton, 1990). The strengths of this format are (1) the interviews remain fairly conversational and situational, and (2) the outline increases the comprehensiveness of the data and makes data systematic for each respondent (Patton, 1990). However, the flexibility in sequencing and wording questions can result in substantially different perspectives, and thus reduce the comparability of responses.

There are four reasons for this research adopting a more open-structured style of interview. (1) Considering the background in Taiwan, where most of the interviewees (both students and lecturers) may have never before participated in a research interview, a conversational style of interview was expected to eliminate their hesitation when responding. (2) An informal style of interview was particularly required for the lecturer interviews due to the status of the researcher and the interviewees. It could have been offensive to the researcher's colleagues if they were interviewed under a well-structured format. (3) As explained in section 1.1, since there is a lack of research information in the same context as this research, a more open style of interview was hoped to broaden the understanding of the existing situation as a result of this study in Taiwan. (4) Unified format questionnaire surveys were distributed following both student and lecturer interviews. The results of these surveys were expected to compensate for the weaknesses of this type of open-form interview.

- ***The strengths and the weaknesses***

Bell J. (1993) argued that one of the major advantages of the interview is its adaptability. She noted that a skillful interviewer can follow up ideas, probe responses, and investigate motives and feelings, which the questionnaire can never do (p.91). Best and Kahn (1993) concluded that the strengths of interview are that the interviewer can (1) explain more explicitly the purposes and the questions, and allow following clarification when the subjects misinterpret

questions, (2) evaluate the sincerity and the insight of the interviewees, and (3) explore significant areas, which are not anticipated originally.

On the other hand, the weaknesses of interviews are (1) The interview is time-consuming, and thus strictly limits the number of subjects; (2) The interviewer needs to be highly skilled in order to induce respondents' engagement; (3) The interview data are usually unsystematic, and thus result in difficulty of analysis, and (4) The interview and analysis processes can be highly subjective, so that there is always a danger of bias (Best and Kahn, 1993; Borg, 1981; Cohen and Manion, 1995).

Suggestions for interviewers to develop the strengths and eliminate the weaknesses are also found in the literature.

- ***Suggestions for conducting interviews***

Best and Kahn (1993) suggested that in order to obtain reliable and objective data, interviewers must be carefully trained in the skills required to develop rapport, in asking probing questions, and in preparing the interview questions. They claimed that the key to effective interviewing is establishing rapport. Meanwhile, preparation for the interview is a critical step in the procedure. They noted that the interviewer must (1) have a clear conception of what information they need and (2) clearly outline an optimal sequence of questions to stimulate the responses. They suggested that a written outline, or checklist can ensure the interviewer will cover all key issues during the interview.

Millar and Cannell (1988) suggested that the most efficient method of monitoring interviews has been to audio record the interview and code the transcript. In addition to the words, the tone of voice and emotional impact of the response are preserved by the tapes, and may provide critical clues when analyzing.

3.1.5 Questionnaire survey

This research contains several student questionnaire surveys, which are mainly in a closed-form.

- *The strengths and the weaknesses*

The reasons and strengths of adopting this type of research technique can be discussed as follows.

Firstly, questionnaire surveys can be made by mail. This strength was critical to the researcher, since the research location (Taiwan) was distant from the researcher's country of study (New Zealand). In the early stage of this research, two sets of student questionnaire surveys were made by mail, and provided the researcher with a preliminary understanding of the existing situation, clarifying the foci of the following research. Secondly, the survey can be distributed to a large numbers of subjects and thus provide a macroscopic understanding of the situation. As explained in section 1.1, Feng-chia University has 2000 students taking this course every year, and thus the large enrollment has benefited the quantitative investigation. Thirdly, the survey process is highly objective since the researcher does not directly interact with the participants. Fourthly, the survey is anonymous, which encourages the honesty of the responses. The large number of participants, avoidance of interaction between the researcher and respondents, and anonymous format create the reliability of the results. Finally, the objective characteristics of the survey may be more convincing to the physics lecturers due to their experiences in physics research. The quantitative results may also be more highly appraised by physicists than qualitative descriptions, since they are used to adopting numbers to interpret the observed phenomena.

However, researchers may need to be aware of the possible problems that questionnaire surveys may cause. Firstly, the same words may mean different things to different people, and the respondents may have many different interpretations of the questions. Secondly, the questions need to avoid ambiguity and jargon, and require the researcher to have a good understanding of the subjects' background. The researcher took advantage of her teaching experience, which may have reduced this weakness. Thirdly, unlike interviews, questionnaire surveys do not allow for further investigation of certain significant issues, unless a following survey is conducted. Best and Kahn (1993) noted that when designing questionnaires the researcher must have a clear idea of what he/she wants, but many beginning researchers are not very clear about what they want. Based on

this consideration, this research usually conducted a second investigation following the preliminary surveys. Finally, it is hard to monitor the motivation of the respondents in answering the questionnaire. The researcher was particularly aware of this problem, considering the Taiwanese traditional culture. Taiwanese students are taught to be obedient to the teachers, and thus they may not be used to refusing to participate in research, even if they are not willing to. The researcher had to emphasize the voluntary basis of the survey while addressing the importance of their participation.

- ***Suggestions for questionnaire design and presentation***

Best and Kahn (1993) defined the criteria of good questionnaire design as (1) dealing with significant topics, (2) as short as possible, and only long enough to get the essential data, (3) making the response systematic and easy to complete, and (4) each question dealing with a single idea. Bell J. (1993) noted that when delicate questions are necessary, the questionnaire should be anonymous, and sensitive issues should be left to later in the questionnaire. Best and Kahn (1993) suggested the order of the questionnaire as proceeding from general to more specific responses, from simple to complex questions.

With respect to the presentation of the quantitative survey results, tables and charts are two major tools to illustrate the data. Chapman and Mahon (1986) gave suggestions for designing tables and charts. They suggested that figures are good for communicating non-specific quantitative comparison, while tables are more appropriate for communicating specific amounts. They also gave suggestions for designing tables including: (1) It is easier to compare figures in columns than in rows; (2) Rounding the entries can simplify the information and help readers to clarify the ideas. Meanwhile, they noted that you should not attempt to put too much information in one table or one chart, and suggested breaking a complicated table/chart into several simple ones to help the reader understand the key issues.

The above section has discussed the characteristics of different research methods based on the literature and the practical considerations of using these methods in this research. The next section will give an overview of this research design.

3.2 An overview of this research

In this section, all of the research activities and their structure are briefly introduced, and they are presented in two ways: one way follows the order of the three research phases, and the other is based on the sequence of the five research tasks

The activities which relate to these research phases are presented in the next section.

3.2.1 Research design in each phase

The design of each phase of research is presented in Table 3.1.

Table 3.1 lists a chronology of the research design, including research activities, applied time, participating subjects, and the purposes/questions of each research activity.

Phase 1 included two surveys: survey 1F and survey 1S. Survey 1F was distributed to the first year students when they were just entering university. The purposes of survey 1F were to (1) investigate their original learning attitudes towards and expectations of the university physics course, and (2) understand the students' prior experiences in learning high school physics. Survey 1S was distributed to the second year students who had completed the university physics course. The purpose of survey 1S was to understand the students' perceptions of and comments on the university physics course.

Phase 2 included both student survey (survey 2) and lecturer interviews. Survey 2 made further investigations of the students' perceptions of the course, and of their own learning. The results of survey 2 were also compared with their original expectations of both the course and themselves (from survey 1F). The lecturer interviews aimed to understand physics lecturers' opinions with respect to the teaching and learning of university physics.

Table 3.1 The chronology of research design

Activities	Timing	Subjects	Purposes/ Questions
Phase1 (Oct., 97)			
survey 1F	Oct, 97	206 1st year students	expectations of UP ¹ and perceptions of high school physics
survey 1S	Oct, 97	256 2nd year students	perceptions and evaluation of learning and teaching in UP
Phase 2 (Apr., 98)			
survey 2	Apr, 98	330 students	Perceptions of the course and learning
lecturer interview	Apr, 98	8 physics lecturers	comments on teaching and learning
Phase 3 (Sep. - Oct., 98)			
survey 3A	Sep, 98 ²	222 students	expectations and perceptions of learning and teaching UP
pre-tests	Sep 98 ³	161 students (3 classes)	understanding incoming students' background
survey 3B	Oct, 98	380 students	evaluation of learning and teaching UP, comparison of intervention and traditional
student interview	Oct, 98	14 intervention students	evaluation and suggestions of the intervention teaching
lecturer survey	Oct, 98	7 physics lecturers	opinion transition between phases 2 and 3, comparison of lecturer, researcher, and students' responses
post-tests	Nov 98 ⁴	165 students ⁵ (3 classes)	evaluate academic achievements in different teachings

Phase 3 included an implementation of intervention teaching, and thus the main research purpose of phase 3 was to evaluate the intervention program, compared with traditional teaching. The research methods adopted in phase 3 to evaluate the program included: surveys, interviews and achievement tests. Two student

¹ University Physics course

² In the first week of the new academic year. The same timing as survey 1F and 1S but one year later.

³ Achievement pre-tests were conducted in the 1st week of the first semester.

⁴ Achievement post-tests were conducted in the 7th week of the first semester.

⁵ Subjects in the post-test were mostly the same as those in the pre-test.

surveys were distributed before (survey 3A) and after (survey 3B) the intervention program, to compare the students' opinions of the course with respect to different teaching designs. Meanwhile, 14 intervention students were interviewed during and after the intervention teaching. In addition, students' academic achievements were also measured by two standardized tests both before (pre-tests) and after (post-tests) the program. Therefore, phase 3 of the research included both quantitative and qualitative evaluation of the intervention program in learning attitudes, perceptions of the course, and academic achievement. Besides the evaluation of the outcomes of the intervention program, lecturers' opinions of the course were further investigated during phase 3, and compared with those found in phase 2.

The above discussions introduce the activities with respect to each research phase. The next section will explain these activities corresponding to each research task.

3.2.2 Research activities and research tasks

This research included five tasks in sequence. Since the activities corresponding to the sequence of the tasks were not completely consistent with the chronology of the three research phases, the activities based on the five research tasks are also presented. The five research tasks and the corresponding activities are listed in Table 3.2.

Table 3.2 Research activities with respect to each research task

Research tasks	Research activities (timing)
1. Understanding the situation of the incoming students: expectations, attitudes, and physics background	survey1F (phase 1) survey 3A (phase3) achievement tests (phase 3)
2. Evaluating the UP course: students' and lecturers' views on UP course design, teaching performance, and learning	survey1S (phase 1) survey 2 (phase 2) lecturer interviews (phase 2) lecturer survey (phase 3)
3. Designing the intervention (By the researcher)	(between phases 2 and 3)
4. Implementing the intervention	3 weeks intervention teaching (phase 3)
5. Evaluating the intervention: comparing the traditional and intervention students' opinions and performances	surveys 3A and 3B (phase 3) student interviews (phase 3) achievement tests (phase 3)

Table 3.2 shows that some research tasks included more than one research activity, in different phases. For example, the incoming students' attitudes and expectations were investigated by both survey 1F (in phase 1) and survey 3A (in phase 3). Students' perceptions of learning university physics were investigated by both survey 1S (in phase 1) and survey 2 (in phase 2). Lecturers' views were explored by both lecturer interviews (in phase 2) and a lecturer survey (in phase 3). The first investigation provided the researcher with a better understanding of the situation of the research background, as well as enhancing research competency, and thus, provided a thorough knowledge for further investigation. Therefore, a second time investigation was required to enhance the research findings.

Race (1995) noted that the most important ingredient in a portfolio of skills for successful research is flexibility. He emphasized that there are no formulas for being a competent researcher. He claimed that

successful researchers learn from their mistakes. The real advances are often made when a plan does not work as expected, leading to critical reflection and further creativity in the search for new approaches to a situation (p.80).

Details of the design with respect to each research activity will be discussed in the following two sections, and the discussions of each research activity follow the order of those listed in Table 3.2. They are grouped into two parts: part I includes the research activities contributing to the tasks of background understanding (tasks 1 and 2), and part II includes the activities evaluating the intervention teaching program (tasks 4 and 5). The design of the intervention teaching (task 3) is presented separately, since it was based on the findings of background understanding, which were analyzed and presented in chapters 4 and 5, and summarized in chapter 6. Therefore, the design of the intervention teaching is presented in chapter 7.

3.3 Research design (part I): Understanding the existing situation

To understand the existing situation of university physics education in Taiwan consisted of three components: (1) the incoming students' situations, their attitudes, academic background, and expectations, (2) the students' evaluation of learning university physics, which include the teaching style, the course design, and themselves as learners, and (3) the physics lecturers' views of teaching and learning the course.

The design of each part is discussed below.

3.3.1 The incoming students' situations

Three research activities were carried out in order to understand the incoming students' situation. Surveys 1F and 3A aimed to investigate the incoming students' learning attitudes and expectations. Two standardized academic tests were given to evaluate the students' high school physics background. All of the three research activities were conducted at the commencement of the academic year in order to grasp the original situation of the first year students.

- **Survey 1F**

Survey 1F, which was conducted in October 1997, consisted of 206 first year incoming students in four classes. The response rate was as high as 96%, since the survey was held in class. The complete questionnaires of survey 1F in both original Mandarin and translated English forms are presented in Appendix A1.

The questions of survey 1F were closed-form with a five point Likert scales. The questions consisted of four parts: (1) self-expectations and attitudes towards university study, (2) expectations of the goals of university physics, (3) perceptions of the high school physics course, and (4) perceived learning barriers retarding learning effectiveness. Details of each part are explained as follows:

(1) Self-expectations and attitudes towards university study

Many researchers addressed the crucial roles of learning attitudes and learning approaches in determining learning outcomes (eg, Biggs and Moore, 1993; Donald, 1993; Kember, Jamieson, Pomfret and Wong, 1995; Prosser, Walker and Millar, 1996). Therefore, the learners' original attitudes toward the new stage of learning were investigated. Questions in this part focused on learning attitudes and approaches, and the key points are listed in Table 3.3.

Table 3.3 Original expectations of learning attitudes and approaches of the incoming students

Learning attitudes	Learning approach
<ul style="list-style-type: none"> • Being autonomous • being independent • aiming for pass only 	<ul style="list-style-type: none"> • Avoiding rote-learning • being involved in discussion • being critical of teaching material • reading broadly

(2) Expectations of the goals of university physics

Bartlett (1988) noted that we should not talk of improving the course of physics unless we have a clear, or at least an improved, understanding of our broad

educational goals (p.204). Before encountering issues of curriculum design, different opinions on the teaching goals have to be examined (Osborne, 1976). As discussed in the literature, students need to realize the value of the course in order to engage in learning. Therefore, students' expectations of the goals of learning university physics are worth investigating.

In addition to the area of subject knowledge, the application of physics knowledge and the development of learning capacity constitute a broad perspective of viewing the goals of the course. The expected goals are listed in Table 3.4 with respect to these three areas.

Table 3.4 Expectations of the goals of university physics

Subject knowledge	Application of physics knowledge	Learning capacity
<ul style="list-style-type: none"> ● content coverage ● enhancing understanding of physics concepts ● fostering mathematical skills ● enhancing English comprehension 	<ul style="list-style-type: none"> ● application in everyday life ● knowledge in contemporary technology ● providing basis for advanced courses 	<ul style="list-style-type: none"> ● enhancing thinking ability ● promoting learning interest

(3) Perceptions of high school physics course

As discussed in section 2.2.4, students' perceptions of their learning environment were critical to their learning approaches and learning outcomes (eg, Entwistle and Ramsden, 1983; Trigwell and Prosser, 1991). For the incoming students, their experiences of learning high school physics may influence their approach at university. Therefore, the students' perceptions of high school physics were investigated. The key points related to teaching content, and the course overall are presented in Table 3.5.

Table 3.5 Perceptions of high school physics course

Teaching content	Course overall
<ul style="list-style-type: none"> ● relevant to real life 	<ul style="list-style-type: none"> ● induced learning interest
<ul style="list-style-type: none"> ● too much mathematics 	<ul style="list-style-type: none"> ● heavy load
<ul style="list-style-type: none"> ● focused on clarifying concepts 	<ul style="list-style-type: none"> ● teaching pace was too fast

(4) Perceived learning barriers retarding learning effectiveness

The unsatisfactory academic achievement in learning physics, either in high school or university, is regarded as a prevalent problem in many countries (eg, Halloun and Hestenes, 1985; Rowell, Dawson and Pollard, 1993; Sun and Lau, 1996). An understanding of what students perceive as the main factors retarding their learning outcomes in physics is crucial before attempting to modify teaching. Besides insufficient academic background, inappropriate learning habits and unfavorable teaching design are also possible factors to retard learning (eg, Prosser and Trigwell, 1997; Rowell, Dawson and Pollard, 1993; White *et al.*, 1995). Therefore, the key points are categorised into three groups and listed in Table 3.6.

Table 3.6 Perceived barriers retarding learning physics

Academic background	Learning habits	Teaching design
<ul style="list-style-type: none"> ● weakness in physics background 	<ul style="list-style-type: none"> ● insufficient study hours 	<ul style="list-style-type: none"> ● teaching style monotonous
<ul style="list-style-type: none"> ● insufficient mathematical ability 	<ul style="list-style-type: none"> ● inappropriate study strategies 	<ul style="list-style-type: none"> ● content too boring ● pace too fast ● failed to give lucid lessons ● lack of consulting resources

After analyzing the results of survey 1F, and obtaining a preliminary understanding of the students' original learning attitudes and background, a second investigation (survey 3A) was made in the following year to gain a better

insight into the incoming students.

- **Survey 3A**

Survey 3A (phase 3) was carried out in September 1998, and included four classes - 222 first year students. The intervention class was one of the participating classes so that the homogeneity of the intervention class in comparison with others could be examined.

The key issues of survey 3A were similar to those of survey 1F, while questions in survey 3A were more specific. Complete questionnaires of survey 3A, both in Mandarin and translated English format are presented in Appendix A4.

Questions in survey 3A were mostly closed-form with a five-likert scale, and followed by two open-ended questions. The closed questions consisted of four parts: (1) basic information about the respondents, (2) the expected goals of university physics, (3) anticipated learning strategies/commitment, and (4) expected teaching strategies.

Basic information included (1) ages, (2) types of high school: public or private, and (3) high school physics study hours in class, etc. The information was required to examine the previous study background of the students.

The questions of the expected goals of university physics were similar to those in survey 1F, which are listed in Table 3.4.

In contrast to the more general questions in survey 1F, more specific learning strategies were investigated in survey 3A. These questions can be categorized as surface-level and deep-level strategies, and learning commitment. The key points of the questions in each group are listed in Table 3.7.

Table 3.7 Expected learning strategies and commitment of incoming students

Surface-level	Deep-level	Learning commitment
<ul style="list-style-type: none"> • copy notes verbatim • learning physics alone • focus on problem-solving • memorizing formulas only 	<ul style="list-style-type: none"> • actively discuss questions with others • synthesize concepts in different topics 	<ul style="list-style-type: none"> • genuine willingness to attend • anticipated study hours out of class

Similarly, the expected teaching strategies were specifically investigated in survey 3A. These questions related to teaching content, teaching approach, and adoption of teaching aids, and the key phrases of the questions are presented in Table 3.8.

Table 3.8 Expected teaching strategies from incoming students

Teaching content	Teaching approach	Adoption of teaching aids
<ul style="list-style-type: none"> • cover all content in textbook • clarify important concepts • focus on problem-solving • relevant to everyday life 	<ul style="list-style-type: none"> • be aware of learning • encourage interactive learning • give humorous lectures 	<ul style="list-style-type: none"> • give hand-outs • do demonstrations • provide information for extra reading

In addition to the students' original expectations and attitudes of learning university physics, the incoming students' physics background was examined as well.

- *Academic tests*

Accompanying survey 3A, the students' high school physics background was assessed by way of two tests: a traditional problem-solving test and a "pure" concept test. These two tests were given together to three classes (161 students), and the intervention class was one of these classes. In addition to examining the students' original physics background, the results of these tests were also

compared with the post-tests to evaluate the students' learning achievement, under different teaching methods.

The concept test used was called the *Force Concept Inventory*, which was designed by Hestenes, Wells and Swackhamer (1992) to evaluate the students' understanding of Newtonian concepts. They summarized the findings of abundant research into misconceptions about mechanics, and designed the original version of the test. The Force Concept Inventory contains 29 questions, which are limited to concept understanding without mathematical manipulations.

The other tool used was a traditional problem-solving test, called the *Mechanics Baseline Test*. This tool was designed by Hestenes and Wells (1992). They noted that although the test looked just like the end-of-chapter problems, when designing the tool they excluded problems that simply require "plug-in" of numbers into the formula.

Both the Force Concept Inventory and Mechanics Baseline Test are in multiple-choice format. These two tools have been revised via several evaluations of the reliability and modifications of the tools, by comparing the results of the official multiple-choice format with an open-ended written format, and interview (Hestenes, Wells and Swackhamer, 1992; Hestenes and Wells, 1992). These tools were also evaluated by making a comparison with the performance of several graduate students' in these two tools, and their achievements in the graduate classical mechanics course. The two sets of results were fairly consistent.

Reasons for this research to select these two tools to evaluate the students' academic performance included:

- (1) These tools have been widely adopted in the US, and there is much data available of the American students' results, both in their high school background and gain due to learning university physics (eg, Hake, 1997). Since the physics courses in Taiwan mainly adopt the American textbooks, and the textbook has played a central role in curriculum design, it would be necessary to examine whether the two groups of students are similar in physics background before adopting a similar curriculum design. Besides, the

quantitative standardized tests referenced with abundant data may be more persuasive to physics lecturers than qualitative evaluations lacking reference.

- (2) These tools have been evaluated and modified several times after the original design and are regarded as reliable. The tests utilized in this research were the latest versions, which were slightly different from the initial versions (Mazur, 1996).
- (3) The topic of these two tests is classical mechanics, which is consistent with the teaching topics at the corresponding research phase (phase 3).
- (4) The time for completing the two tests requires around 60 minutes, which is feasible in the normal teaching time at Feng-chia University.
- (5) Although several researchers argued the problematic nature of the multiple-choice format (eg, McDermott, 1997) as well as the students' motivations in participating in the written examinations (eg, Rennie and Punch, 1991), the results can provide a rough understanding of the Taiwanese students' background and learning achievement in a convenient and inexpensive way.

Considering the subjects' English reading comprehension, the researcher translated both the Force Concept Inventory and Mechanics Baseline Test into Mandarin. To ensure the appropriation of translation, two Taiwanese, possessing degrees in physics, were invited to answer the Mandarin version of the tests. The researcher slightly modified the Mandarin translation according to these two participants' suggestions.

The complete questions of these two tests, in both the original English form and translated Mandarin form, are attached in Appendixes C1 and C2.

This section has introduced the research design in investigating the incoming students' original situations, including their learning attitudes towards the new stage of study, previous learning experiences, and academic background. The next section will discuss the research in understanding the students' perceptions of learning university physics.

3.3.2 The students' perceptions of learning university physics

Investigating the students' perceptions of learning university physics comprised two surveys: survey 1S and survey 2.

- *Survey 1S*

Survey 1S was carried out in October, 1997 (phase1) and included 256 second-year students, who had just completed the course. The questionnaire of survey 1S was mostly parallel with that of survey 1F. Survey 1S was in closed-form, and consisted of four areas:

- (1) goals of the university physics course,
- (2) perceptions of the course design,
- (3) learning barriers in retarding performance, and
- (4) evaluations of teaching performance.

With respect to the goals of the course, the students' expected goals and their perceptions of the achievement of these goals were both investigated. The results provided information about the students' satisfaction with their achievement in learning university physics as well as comparing the consistency of the course design and the students' expectations. The items of survey 1S were similar to those in survey 1F, which are presented in Table 3.4.

Similarly, the questions of the students' perceptions of university physics (in survey 1S) were consistent with those of the incoming students' perceptions of high school physics (in survey 1F). The key points of the questions are presented in Table 3.5.

Most of the questions concerning the students' perceived barriers retarding their learning in survey 1S were similar to survey 1F, except that survey 1S added the factor of English reading comprehension, since university physics adopts the textbook in English. The difficulty of Asian students dealing with the English textbooks was reported by Sun and Lau (1996).

There were six questions with respect to the physics lecturers' teaching ability and performance, in both the students' evaluations and expectations of being a good physics lecturer. The purposes of these questions were to examine the students' satisfaction with respect to the lecturers' teaching, as well as to understand the students' perceptions of the characteristics of a good physics lecturer. These questions included (1) adopted teaching strategies and (2) teaching ability, and the key points of these questions are listed in Table 3.9.

Table 3.9 Expectations and evaluations of teaching performance

Teaching strategies	Teaching ability
• encourage discussion in class	• sufficient physics knowledge
• adopt a variety of teaching methods	• explain ideas clearly
• supply application examples	• establish good classroom atmosphere

The results of survey 1S provided the researcher with a preliminary understanding of students' perceptions of the course design, and their major concerns about factors determining teaching and learning outcomes.

- **Survey 2**

Based on the information obtained in survey 1S, the researcher designed a following questionnaire to investigate the students' opinions in survey 2. Survey 2 was distributed to the first year students in the third quarter of the academic year.

Owing to the research experience and information of survey 1S, survey 2 has some significant differences in design compared with survey 1S. A complete copy of survey 2, in both English and Mandarin, is given in Appendix A3.

Firstly, the closed questions were modified from the five-likert scale used in survey 1S to three levels, agree, disagree, and neutral, in survey 2. The results in survey 1S showed that the respondents tended to avoid selecting the options at opposing ends: completely agree and completely disagree, therefore, it may be

more appropriate to simplify the options to three scales.

Secondly, the questions in survey 2 added the evaluation of students' affective learning outcomes, such as the appeal, tediousness, and difficulty of the course as perceived by the students. Meanwhile, survey 2 added certain questions to investigate the students' self-evaluations of their learning strategies and learning habits. These additions were influenced by those articles highlighting the importance of learners' affective responses, metacognitions, and adopted learning approaches in determining learning outcomes (eg, Baird, Fensham, Gunstone and White, 1991; Rennie and Punch, 1991; Trigwell and Prosser, 1991).

Thirdly, open-ended questions were introduced in survey 2 accompanied by closed questions. The open-ended questions were hoped to be beneficial to broaden the perspectives of the researcher dealing with the research issues.

The closed questions of survey 2 consisted of four parts, which were the students' evaluations of (1) teaching content, (2) teaching approaches, (3) the course overall, and (4) self-evaluation of their learning. There were 23 closed questions in total, and their key points are listed with respect to each part in Table 3.10.

Table 3.10 Students' evaluation of teaching and their own learning

Teaching			Learning
teaching content	teaching approaches	the course overall	self-evaluation
<ul style="list-style-type: none"> • repetitive • insufficient life examples • expect more modern topics • lack of integration 	<ul style="list-style-type: none"> • teaching style is appealing • expect more interactive teaching • traditional lecture is appropriate • expect more demonstrations 	<ul style="list-style-type: none"> • pace too fast • too difficult • very boring • the course is worthwhile • promotes learning interest 	<ul style="list-style-type: none"> • being autonomous • adopted flexible approach • discuss with others • reflect and modify learning approach • concentrate on lecture • rote-learning • aim for pass only

In addition to the closed questions, three open-ended questions were posed in survey 2. The criteria of designing open-ended questions included a balance of positive and negative statements to avoid possible bias and minimizing the presumptions to induce alternative responses in order to develop the researcher's perspectives.

The three open-ended questions asked the students to point out (1) the strengths to maintain and (2) weaknesses to modify in the existing curriculum design, and (3) to give a comment on the course overall.

In summary, both survey 1S and survey 2 provided a better understanding of the students' perceptions of the teaching and learning of the course. The results of the students' evaluations of the teaching and their own learning were also compared with the results of the incoming students' expectations. The comparison can help to achieve a better understanding of the consistency between the students' expectations and the actual course design, as well as the fulfillment of the students' self-expectations and their actual learning commitment and achievement.

In addition to the students' points of view, the lecturers' views were also investigated to gain background understanding.

3.3.3 The lecturers' views

In curriculum design, lecturers' views play a crucial role since lecturers are dominant in deciding the curriculum at Feng-chia University. As mentioned earlier, Feng-chia University has ten physics lecturers in addition to the researcher. This allowed the researcher to investigate the general opinions of the lecturers' views in a convenient way.

The lecturers' views were investigated via two research activities: lecturer interview (in phase 2) and lecturer survey (in phase 3).

- ***Lecturer interview***

The lecturer interview was conducted in April 1998. Eight physics lecturer interviews were completely audio-recorded. In addition, one lecturer agreed to the

interview but disagreed with audio recording the process, and thus the researcher had to take notes while interviewing. Considering the incompleteness of the note taking, this data was discarded. Therefore, the valid data includes eight lecturers' opinions.

The interview was made on a one-to-one basis, and each lecturer was interviewed once. Although the researcher had advised that the required time was around 30 minutes, the actual interview duration was mostly extended to around one hour. None of the interviews were under 45 minutes, and two interviews were over the one-tape length: 90 minutes. The participating lecturers expressed their sincere intention to *discuss* the issues with the researcher, and thus made the interviews longer than originally planned. Their genuine engagement in the interviews enriched the research findings as well as encouraged the researcher's devotion to this study.

Outlines of the lecturers' ^{interviews} are listed in Appendix B1. The issues of the lecturer interviews consisted of two main areas: the course design and the learners.

The course design contained five parts:

- (1) the goals of the course, including subject knowledge, personal development etc.,
- (2) the teaching content design, such as content selections, structure and the textbook,
- (3) alternative teaching approaches, including the options of alternative teaching approach with respect to traditional lectures, existing barriers and potential strengths of adopting these options,
- (4) assessment strategies, such as the role of assessment in teaching and learning, opinions of the existing assessment system,
- (5) the unified curriculum system, including positive and negative opinions about the system.

The issues about learning included three parts:

- (1) lecturers' evaluations of the learning, including both affective and academic outcomes,
- (2) lecturers' perceptions of the learning attitudes, including their learning motivations, learning commitment, and learning approaches, and
- (3) main learning barriers retarding the students' academic performance.

Since the interview process was not highly structured, many questions overlapped in different issues. For example, issues of content selection were highly related to those of the goals of the course as well as the unified curriculum system.

The results of the lecturer interviews provided a better insight into the lecturers' perceptions and opinions of the existing teaching and learning. Based on the findings, the researcher designed a second tool to investigate the lecturers' opinions further in the lecturer survey.

- *Lecturer survey*

The lecturer survey was made in phase 3 (in September 1998), which was five months after the lecturer interviews. The questions were mostly in an open-ended form, while the researcher provided some options in several questions to facilitate their responses. A complete copy of the lecturer survey, in both English and Mandarin, is given in Appendix B2.

Seven physics lecturers responded to the questionnaire. When the questionnaire was given to the lecturers, their previous students' responses in survey 2 were also attached to them as references.

There were two main reasons for the lecturer survey. Firstly, as explained earlier, the lecturer interviews were in an open-form, and the interview structure caused a certain degree of difficulty in making precise manipulations when comparing opposing opinions. A questionnaire survey could rectify this shortcoming. Secondly, the students' opinions (survey 2) appeared to be widely divergent from those expressed in the lecturers' interviews. It was considered worth investigating the responses of the lecturers when presented with their students' opinions. The lecturers' responses could indicate their attitudes towards their students' opinions,

as well as their evaluation of education research. Their responses could have implications for the practical application of this research.

The questionnaire of the lecturer survey consisted of four parts:

- (1) responses to students' opinions (in survey 2) overall,
- (2) opinions about the research design of survey 2,
- (3) suggestions for improving teaching, both in teaching content and teaching approach, and
- (4) considerations and suggestions for promoting learning engagement.

In summary, the lecturers' views were investigated in two steps. Lecturer interviews provided the researcher with a qualitative understanding of the lecturers' opinions with respect to the course design, teaching experiences, and comments on the students' performance. The lecturer survey provided a quantitative comparison of the lecturers' opinions, and further information on the lecturers' suggestions with respect to curriculum innovations. The lecturers' views were also analyzed and compared with both the students' views and the notions of the contemporary literature.

This section has described the research methodology aimed to understand the existing situations of university physics education in Taiwan. Research findings of the existing situations will be analyzed and discussed in chapters 4, 5 and 6. Based on these findings, the researcher designed and implemented an intervention teaching program, which is presented in chapter 7. The next section will describe the research design for evaluating the intervention teaching.

3.4 Research design (part II): Evaluating the intervention teaching

The evaluation of the intervention teaching included both the students' perceptions of the course design and their learning, and the students' academic achievements, comparing the intervention class with the traditional classes. To

understand the students' perceptions required quantitative and qualitative investigations, and a quantitative evaluation was adopted with respect to the students' academic achievements. The evaluation of the intervention students' perceptions and their academic achievements compared with those of the students in the traditional classes will be described in the following two sections.

3.4.1 Evaluations of the students' perceptions

Both a survey (survey 3B) and an interview (students' interview) were conducted to evaluate the students' perceptions of the intervention teaching.

- ***Survey 3B***

Survey 3B was conducted right after the completion of the intervention teaching program (in October 1998), which included the intervention class and seven other traditional classes. The subjects included 53 intervention students and 327 students in the traditional classes. The intervention class was taught by the researcher, and the seven traditional classes were taught by seven other lecturers.

According to the results of survey 1S and 1F (in phase 1), the students appeared to be reluctant to select the items which were stated with as strong a word as completely. Therefore, a modification was made in survey 3B, which included 24 closed questions and two open-ended questions. The closed questions gave options using the five-likert scale. Unlike the statements of survey 1S and survey 1F, the options of the five-likert scales in survey 3B avoided strong phrases in the opposing options. The comparison between the two types of statements is listed in Table 3.11.

Table 3.11 Modifications of option statements in a later survey

Corresponding number	5	4	3	2	1
Survey 1S, 1F	Completely agree	Agree	Neutral	Disagree	Completely disagree
Survey 3B	Agree	Slightly agree	Neutral	Slightly disagree	Disagree

The purpose of the alternation in survey 3B was to induce wide-spread responses in order to identify subtle differences between different clusters of students.

The design of the questions in survey 3B was mainly based on the expected aims of the intervention program in order to evaluate the outcomes of the program. A complete copy of survey 3B, in both English and Mandarin, is given in Appendix A5.

Similar to the design of survey 2 (see section 3.3.2), the closed questions in survey 3B also consisted of the four domains of the students' evaluations of (1) teaching content, (2) teaching approaches, (3) the course overall, and (4) self-evaluation of their learning. The key phrases of each question are listed with respect to each domain, in Table 3.12.

Table 3.12 Students' evaluation of intervention teaching

Teaching			Learning
teaching content	teaching approaches	the course overall	self-evaluation
<ul style="list-style-type: none"> • Induce learning interest • Link to everyday life • Should reduce mathematics • Clarify the key points • Concepts not integrated 	<ul style="list-style-type: none"> • One-directional delivery • Methods are monotonous • Be aware of learning • Be involved in discussion 	<ul style="list-style-type: none"> • Promote interest in physics • Feel satisfied • Reinforce learning confidence • Develop thinking • Enjoyment • Good achievements • Enhance physics concepts 	<ul style="list-style-type: none"> • Concentrate on listening • Willingness of attendance • Deep-learning strategy • Prefer interactive teaching • Learn nothing • Aim for pass only • Study hours

In addition to the closed questions, the two open-ended questions were also similar to those in survey 2, asking for the strengths and weaknesses of the course in general.

- *Student interviews*

The student interviews were conducted during and after the intervention teaching program. Fourteen intervention students were interviewed during the 3-week intervention teaching, and four of them had second interviews after the completion of the program. The students were recruited under a volunteer basis.

Both individual interviews and group interviews, which included no more than four interviewees, were adopted. An outlines of the student interview questions is given in Appendix A6.

Based on this research, the researcher found that individual interviews are prone to be well structured, which is easier to analyze, while group interviews can provide better opportunities to inspire unexpected issues, and are more relaxed.

During the group interviews, there were often conversations and debates amongst the interviewees, during which the researcher behaved more like an observer, which reduced potential bias from the interviewer. When each interviewee had already had an individual interview, there were no problems for the researcher to distinguish each participant when analyzing the group interview.

The main issues of the student interview included:

- (1) teaching content design, which contained both content selection and content structure,
- (2) the interactive style of teaching, which included the comparison of the traditional teaching style, existing barriers of implementation, the strengths, and their suggestions for modifications, and
- (3) their own learning, which included learning approach, learning tasks, and perceived learning barriers.

The student interview usually started from an open question asking whether they perceived any differences in the intervention teaching, when compared with their previous study experiences. Since the intervention teaching program was implemented at the beginning of the academic year, and the students had not received any traditional teaching in university physics, the students were thus asked to compare the differences between intervention teaching and their high school physics classes.

Individual interviews took about 40 minutes, while group interviews were mostly over one hour. All of the student interviews were audio-recorded with the participants' agreement.

Considering the possible bias that the researcher acted as both the program designer as well as the interviewer, the results of the anonymous survey could examine the reliability of the students' opinions in the interview.

3.4.2 Evaluations of the academic achievements

In addition to evaluating the students' perceptions of the different teaching design,

the students' academic achievement was also assessed.

Pre-tests and post-tests were used to assess the students' achievements. The pre-tests were also utilized to evaluate the incoming students' physics background. The design of the diagnostic tests is detailed in section 3.3.1.

Since the topic of the tests covered the whole of classical mechanics, the post-tests were not given until four weeks after the completion of the intervention program to match the coverage of teaching.

Considering that the duration of the intervention teaching was only three weeks, a markedly increase in academic performance was not expected. Taking this into account, the researcher applied a more convenient way of investigation, ie, standardized tests with multiple-choice format.

In summary, the evaluations of the outcomes of the intervention program included the students' evaluations of the course, perceptions of their learning, and academic performance. The closed questions of survey 3B and the academic tests provided quantitative evaluations, and the student interview and the responses to the open-ended questions in survey 3B provided qualitative evaluations of the program.

3.5 Summary

In summarizing the methodological design of this research, three significant features emerged.

Firstly, most of the research tasks contained a follow-up investigation. This allowed the researcher to undertake thorough investigation, and provided opportunities for evaluating the consistency of the findings.

Secondly, most of the research tasks also contained a combination of both closed and open-ended form at investigations, which allowed both quantitative and qualitative analysis of the research findings. This provided a balance between broadness and in-depth understanding.

Thirdly, as her research experience accumulated, as a result of designing the tools, conducting the activities, and particularly analyzing the data, the researcher noticed the complexity of human feelings and thinking, and thus gradually abandoned her previous commitment to an empirical way of viewing research methodology. An open-form of investigation accompanied with qualitative analysis can penetrate the subjects' mind, and this is essential in education research. The shift of the researcher's epistemological beliefs led to a tendency to modify the research design of this thesis from a fixed, closed approach to an open approach.

Chapter 4

Understanding the existing situation: Students' views

In this chapter, the students' opinions will be investigated in order to gain a better insight into their perceptions about learning the course. Five areas will be discussed:

- (1) teaching goals of the course and content selection,
- (2) evaluation of the course: results of closed questions,
- (3) evaluation of the course: results of open-ended questions,
- (4) physics lecturers and teaching performance, and
- (5) self-expectation and self-assessment of the learners.

The data discussed in this chapter was obtained from many research activities: survey 1S, survey 1F, survey 2, and survey 3A. Details of these activities are described in sections 3.3.1 and 3.3.2. In the following discussion, the source of the data will be mentioned with respect to each section.

4.1 Teaching goals of the course and content selection

The importance of teaching goals in curriculum design has been emphasised by many researchers (Bartlett, 1988; Osborne, 1976). There is no doubt that content selection plays an important role in achieving the goals of the course. According to some research articles and to the students' perceptions, the boundary between the goals and the criteria of the content selection is hardly distinguishable (eg, Gordon and Aubrecht, 1989; Osborne, 1976; Sun and Lau, 1996). Therefore, criteria of content selection were combined with the teaching goals when designing the questionnaires.

The results of the students' opinions of teaching goals are taken from surveys 1F and 1S. Both of these surveys were conducted simultaneously in phase 1. Survey 1F was to investigate the first year students who were just starting studying the university physics course; survey 1S was to investigate the second year students who had finished the course.

The selected items were the same for both groups of students and included :

- | | |
|----------------------------------|--|
| (1) more topics (MT) | (2) physics concepts (PC) |
| (3) mathematical arithmetic (MA) | (4) basis for advanced courses (AV) |
| (5) thinking ability (TK) | (6) link between physics and life (LF) |
| (7) new technology (NT) | (8) interest in physics (IT) |
| (9) English reading (EG) | |

Details of the questions regarding the goals of the course were presented in section 3.3.1.

In order to clarify student opinions about the teaching goals of the university physics course, the questionnaires included three parts: (1) expected goals by first year students, (2) expected goals by second year students, and (3) achieved goals by the second year students. The results of each part were analyzed and compared with each of the other parts.

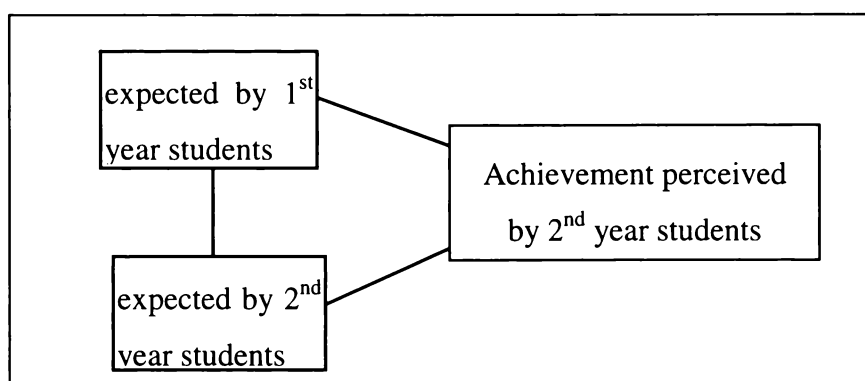


Figure 4.1 Three aspects of the students' views of teaching goals and comparisons amongst them

A comparison of investigated teaching goals from three different points of views.

In the area of teaching goals, four steps are discussed

- (1) students' expectations of the teaching goals,
- (2) comparison of the expectations of the two groups of students,
- (3) achieved goals as perceived by the second year students, and
- (4) suggestions for teaching content design.

4.1.1 Students' expectations of the teaching goals

The students were asked to prioritize their expectations of the teaching goals. Both sets of students' expectations of the teaching goals were very similar. This implies that after one year of learning physics, the learning experiences did not significantly alter their expectations of the teaching goals of the university physics course. Table 4.1 indicates the expected teaching goals as identified by first and second year students. The percentages of the students who selected each item as the first three priorities are given.

Table 4.1 Expected teaching goals

First year students (N=206)		Second year students (N=256)	
Teaching goals	selected %	Teaching goals	Selected %
advanced	64	life	61
life	57	advanced	49
new technology	53	new technology	48
interests	34	Concept	41
concept	25	Interests	29
thinking	23	Thinking	29
English	22	Mathematics	23
Mathematics	6	more topics	11
more topics	4	English	9

Since the responses of the expected teaching goals from the two years of students were very similar, their responses were combined and are discussed together below.

From the table shown above, the importance of the teaching goals can be grouped into three levels: high, medium and low importance, as listed in Table 4.2:

Table 4.2 Students' expectations of the teaching goals: Three levels of priorities.

High priority	Medium priority	Low priority:
basis for advanced courses	physics concepts	more topics
link physics to life	thinking ability	mathematical arithmetic
new technology	interest in physics	English reading

Firstly, the teaching goals with high priority were to (1) provide a basis for advanced courses, (2) link physics to their everyday life, (3) introduce new technology. These three items are similar in that they all show instant benefits for these engineering students, i.e., they are relevant either to their careers or to their everyday life. Secondly, three teaching goals with medium priority were (1) understanding physics concepts, (2) promoting interest in learning physics, (3) enhancing thinking ability. Lastly, items that were least expected by the students as goals of the university physics course were (1) developing mathematical skills, (2) improving English reading and (3) covering more new topics.

According to the students' responses, teaching content which linked to their majors, everyday life, and technology was perceived to be not just more interesting, but also to be more valuable to the students. The students viewed understanding physics concepts as less important than other practical usage. Also, mathematical skill was perceived to be one of the least important goals in learning university physics.

Meanwhile, according to the students' expectations, introducing more new topics was regarded as trivial. Only 4% of the first year students and 11% of the second year students selected it as a primary goal of the university physics course. The students' responses may ease the pressure on the lecturers to cover the textbooks. The students' responses can provide the lecturers with a solution to the dilemma of content coverage and reasonable pace.

In summary, the students seemed to view practical usage (ie, relevance to careers and everyday life) as more important than development of personal capability (ie,

learning interest, thinking ability, and mathematical skills). The results implied that the students focused more on instant benefits rather than long-term advantages. Meanwhile, the students seemed not to see the value of the physics course for its own sake (ie, understanding physics concepts), but regarded the university physics course as subordinate to their majoring courses.

The results appeared to mismatch with the current curriculum design (see section 1.1), which is dominated by the lecturers' views. The students' perceptions of the existing course design (see section 4.1.3) and the lecturers' perspectives of the goals of the course (see section 5.2) are investigated and discussed later.

4.1.2 Comparison of the expectations of the two groups of students

The above section regards the students from both years as a whole and provides a brief discussion of their expectations of learning the course. Although students in different years expressed fairly consistent responses, some discrepancies were found and are discussed in this section. Among the nine selecting items of teaching goals, four items were treated quite differently by the two groups of students. The results are listed in Table 4.3 and discussed below.

Table 4.3 Comparison of the first and second year students' expectations of the teaching goals

Teaching goals	Selecting percentages			
	Knowledge for majoring courses	Physics concepts	Mathematical skills	English reading
1 st year	64%	25%	6%	22%
2 nd year	49%	41%	23%	9%

The first transition is in the area of the goals of providing a knowledge basis for the students' majoring courses, and developing their physics concepts. The first year students have a stronger demand than their antecedents for links from physics to their majors. After one year of learning physics, the second year students seemed to be more likely to see the value of the physics concepts, although the importance of physics concepts still did not exceed that of their practical application.

The other significant alteration is the importance between mathematics and English in learning university physics. A certain amount (22%) of the incoming students expected to improve their English reading ability through reading the English version of the physics textbook as a major goal of learning physics, while only 6% of the first year students expected to enhance their mathematical skills as a major goal of learning physics. An interesting result was that the first year students' expectation of learning English was stronger than that of learning Mathematics through learning the university physics course. This result might be surprising to the physics lecturers, who usually spend much teaching time on mathematical derivation but little attention on English. After one year's learning experience, the second year students had greatly altered their expectations regarding the benefits of mathematics and English through learning university physics. The selection percentages for the second year students of mathematical skills (23%) significantly exceeded that for English reading (9%).

Comparing the responses of the two different groups of students, the second year students seemed to be less divergent from the existing curriculum design (see section 1.1). The learning experience may cause shifts in the students' expectations towards those of the lecturers. This result supports the thesis of this research: While lecturers teach, they develop not only students' subject knowledge but also influence students' beliefs of their learning goals through the course. Through the learning process, the students can negotiate and gradually modify their perceptions of the criteria for achievement in the course.

An optimistic way of interpreting the shift may be that the students have experienced achievements in these areas as a result of taking the courses. For example, the fact that a greater percentage of the second year students selected physics concepts and mathematical skills as their expected goals may be due to their achievements in these two areas. On the other hand, a pessimistic interpretation of this shift may be a compromise of the learning experience that some goals are practically impossible to achieve. For example, since the teaching content selection can hardly consider the difference in the students' majors because of the unified policy (see section 1.1), a smaller percentage of the second year students selected knowledge of majoring courses as their expected goals. It

would be useful to investigate further whether the shift is due to satisfaction with achievement in some goals or feelings of hopelessness about the other goals. An investigation of the second year students' perceptions of what goals they have achieved through learning university physics may provide some clues to answer this question.

4.1.3 Achieved goals as perceived by the second year students

The previous two sections have discussed the students' expectations of the goals of the course, ie, what achievements do the students regard as the most important in learning the university physics course. This section considers how the second year students perceive their achievements after one year of studying university physics. The discussion is based on two questions:

- (1) In general, how much did the students feel they had achieved? Did the students feel satisfied with the overall learning outcome?
- (2) Comparing the expected goals, do the achieved goals match the priority of their expectations?

The results of the students' perceived achieved goals are listed in Figure 4.2.

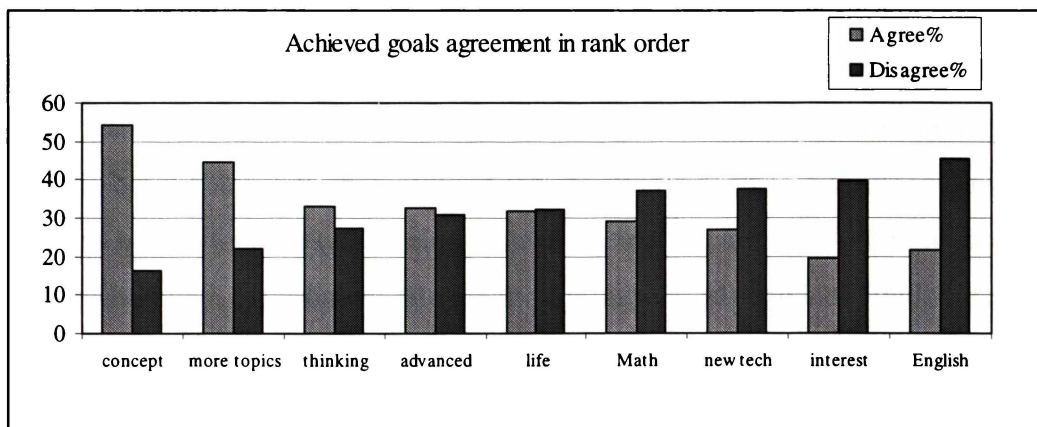


Figure 4.2 The achieved goals as perceived by the second year students: in order of agreement¹

¹ The sum of the two percentages is not necessarily 100% because students could express a neutral opinion.

(1) Overall achieved goals

The agreement and disagreement percentages in all selecting items can answer the first question "to what extent did the students feel that their goals have been achieved?" Unfortunately, the agreement percentages are quite low with most items mainly only around 30%.

The agreement percentages of the achieved goals can be classified into three levels: agree, neutral, and disagree. Results are presented in Table 4.4.

Table 4.4 Rank order of the achieved goals

Levels of agreement	Achieved goals	(agree % / disagree %)
Agree	Physics concept	(54% / 16%)
	More new topics	(45% / 22%)
Neutral	Thinking ability	(33% / 28%)
	Basis for advanced study	(32% / 31%)
	Application in life	(32% / 32%)
Disagree	Mathematical ability	(29% / 37%)
	New technology	(26% / 38%)
	Interest in physics	(20% / 40%)
	English reading	(21% / 46%)

Table 4.4 may imply that the students were not satisfied with the overall learning outcomes. Only two items out of the nine received significant agreement percentages than those of disagreement; they are: developing students' understanding of physics concepts and learning more new topics from the course. On the other hand, less than 30% of the students agreed that learning university physics helped them to (a) develop their mathematical ability, (b) be familiar with new technology, (c) promote interest in physics, and (d) enhance English reading. The agreement percentages were markedly less than the disagreement percentages regarding to these four learning goals.

The next question is which learning goals were better achieved, and were these better achieved goals highly expected by the students? In other words, do the rank order of the achieved goals match the priority of the students' expectations?

(2) Comparison of achieved goals and the expected goals

A mismatch between the students' expectations of the teaching goals and their

perceptions of the achieved goals was revealed for most of the selecting items. The mismatch implied that what the lecturers emphasised in teaching content was discrepant from what the students expected to learn. Three items that were particularly inconsistent between what the students expected and what the lecturers taught were (a) providing examples to link to life, (b) developing interest in learning physics, and (c) introducing more new topics. More details are discussed with respect to each item.

(a) Examples linked to everyday life

In the expected goals, the students strongly expressed that the physics lecturers could introduce more examples linking the physics theory to their everyday life (see Table 4.1). However, their desire seemed not to be fulfilled by the existing course. Out of the achieved teaching goals, life examples were rated sixth out of the nine items. Only one third (32%) of the students agreed that they had learnt the applications from the physics theory. The result implied that the physics lecturers had provided far less life examples than what students anticipated in physics classes.

(b) Interest in learning physics

According to the students' expectations, promoting interest in learning physics was a medium priority compared with other items. However, the outcomes of learning interest appeared to be the second to last achievement out of the nine selecting items. Twice the number (40%) of the students disagreed, compared with those who agreed (20%) that learning physics promoted their interest in physics. The physics lecturers seemed to fail to help most of the students to achieve this affective outcomes.

(c) More new topics

The students addressed the item of more new topics as the least expected goal. However, in the achieved selection, this item appears in the second position as a result of the lecturers' perception. This mismatch implied that the content covered in the existing course seems to be more than what the students expected. In order to cover the content, the teaching pace may become far beyond the learners' ability to cope with. The mismatch of the content coverage may also demonstrate the dissatisfaction of the teaching goals overall. While the lecturers put their

efforts on covering more physics content, they may have sacrificed providing the links between physics and students' life experiences as well as deteriorating their learning interest in return.

4.1.4 Suggestions for teaching content design

Summarizing the above discussion of the students' expectations and perceptions of the teaching goals, four main points are revealed:

- (1) Students from both years possessed similar priorities for the expected goals of the course;
- (2) There was a tendency for the students' expected goals shift towards the actual teaching design when comparing the second year with the first year students;
- (3) The achievement of the teaching goals as perceived by the students was unsatisfactory overall;
- (4) The rank order of the achieved teaching goals as perceived by the students mismatched the students' expectations.

The findings implied that what the lecturers' regarded as important to teach was not what the students perceived as valuable to learn. The mismatch between the students' and the lecturers' expectations of the teaching goals may contribute to the students' dissatisfaction with most of the teaching goals in general.

Based on the summary, suggestions for improvements to the teaching content design include:

- (1) drastically reducing the teaching content coverage,
- (2) emphasizing the enjoyment and relevance of the course by providing more information to link physics theory to practical application,
- (3) modifying the unified policy and providing each lecturer with flexibility to consider their students' majors when designing the teaching content, and
- (4) constantly inviting students to communicate their opinions about the course

design; respecting the students' opinions when modifying the content design.

This section has revealed the mismatch of the teaching goals, and the dissatisfaction of the students with their achievements after studying the university physics course. Based on the findings in this section, the researcher designed a new questionnaire, and conducted a second survey (survey 2) six months later to understand the students' perception of the course overall.

The next section investigates the students' evaluation of the course overall, and searches for the reasons for their criticism and possible ways to improve the current situation.

4.2 Evaluation of the course: Results of closed questions

The second issue in understanding the students' views is to discuss the students' evaluation of the university physics course, mainly in the areas of teaching content, teaching approach and the course overall. The results discussed in this section are limited to the responses of the closed questions. Therefore, the discussion of this section will be mainly on how the students felt about the teaching and the course, rather than searching for the reasons why they felt so. The results were mostly based on survey 2 with a small part from survey 1S. Survey 2 was held at the end of the third quarter of the entire teaching period of the course, and survey 1S was held after the students completed the course. Details of the questionnaire design are discussed in section 3.3.2.

4.2.1 Features of the course overall

With respect to the students' evaluation of the course, two areas are investigated: (1) teaching content design, and (2) feelings about the course overall. The students' responses are discussed below.

(1) Teaching content design

The students' opinions in survey 2 of the teaching content design are shown in Figure 4.3.

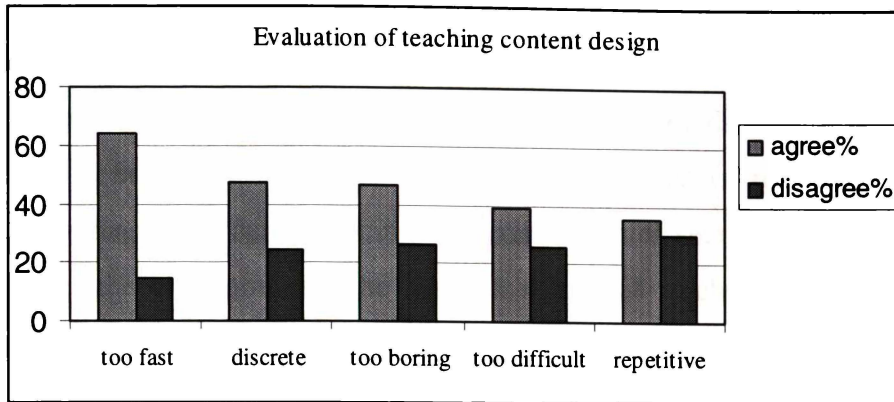


Figure 4.3 The students' evaluation of teaching content design

From the results shown in Figure 4.3, the students seem to have expressed their dissatisfaction with respect to the overall content design. More students agreed than disagreed that:

- (a) the teaching pace was too fast,
- (b) the physics concepts were shown to be discrete rather than integrated,
- (c) the course was very boring,
- (d) the teaching content was very difficult, and
- (e) the teaching content was a repetition of their high school physics.

The strongest criticism was that the teaching pace was too fast, with over 60% of the students agreeing and only 15% disagreeing that the teaching pace was too fast for their learning ability. This finding underpins the mismatch between the students' expected and achieved teaching goals regarding coverage of teaching content (see section 4.1.3). The unreasonable teaching pace may result in other negative perceptions, such as the concepts lacking integration, feeling bored, and increasing the difficulty of learning. Links among these negative perceptions will be discussed later in section 4.2.3. Based on this finding, the teaching content should be drastically reduced to match the students' learning pace. This suggestion is consistent with the discussion of the students' expectations of the teaching goals in section 4.1.4.

The other issue relates to the difficulty of the course. As shown in Figure 4.3, 39%

of the students agreed that the content was very difficult for them, which was slightly higher than the percentage of students who disagreed (26%). Compared with other weaknesses in the course, the agreement of too difficult was lower than that of too boring, discrete, and much lower than that of too fast. The result indicated that the students learning university physics seem to struggle with the fast pace, the boredom, and the discrete nature of teaching physics concepts, rather than with the difficulty of the course. Therefore, from the stance of these Taiwanese students, the problem of difficulty seems not to be as crucial as reported by the literature in western countries (eg, Redish, 1996).

The next step is to investigate the students' evaluations of the course overall.

(2) Students' evaluations of the course overall

The students' evaluations of the course overall were made in survey 2, and the results also showed more dissatisfaction than satisfaction. The results are shown in Figure 4.4.

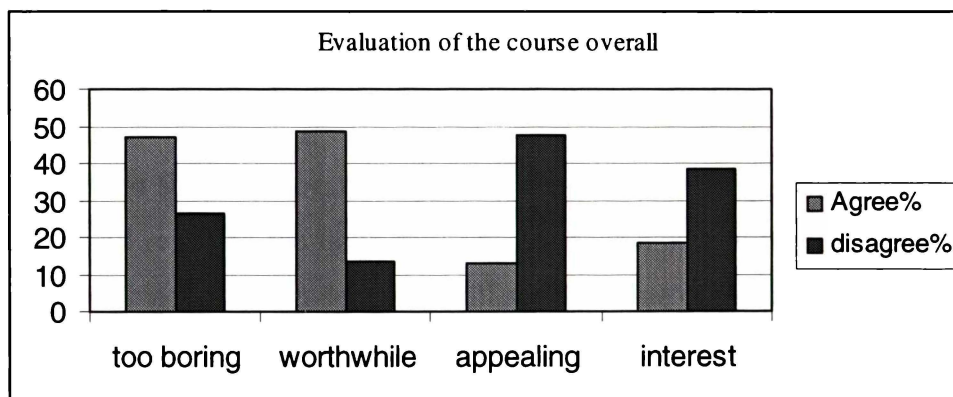


Figure 4.4 The students' assessment of the course overall

The strongest disagreement was that the teaching approach was appealing; 47% disagreed and only 13% agreed with this item. The other problems were that the students felt that the teaching content was very boring, and they also disagreed that they felt interested in learning the course.

The correlation coefficients also showed that the three items of teaching approach not appealing, teaching content boring, and no interest in learning the course were highly linked to each other. The correlation coefficients are shown in Figure 4.5.

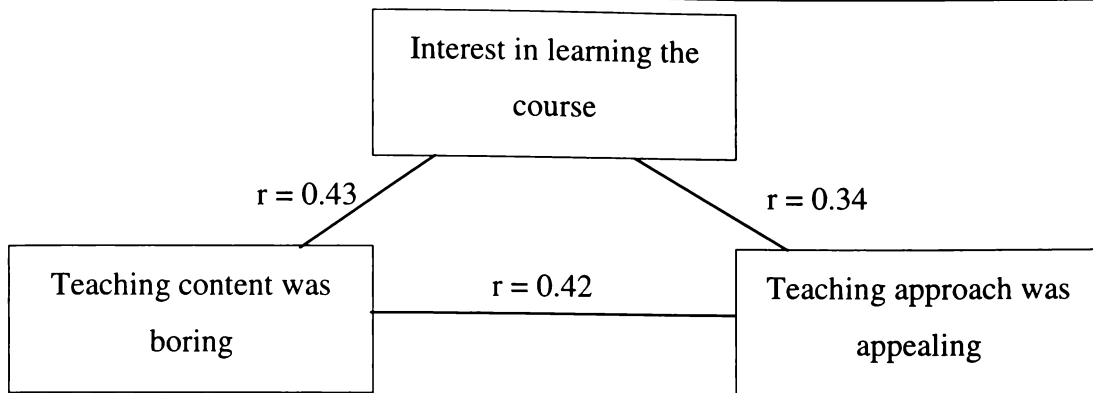


Figure 4.5 Correlation coefficients amongst perceptions of teaching content, teaching approach and interest in the course.

Therefore, the responses of the students may be based on their feelings about the course overall rather than the comments about each individual aspect, such as teaching approach and teaching content.

According to the students' responses, the existing teaching was unlikely to provide the learners with a good impression of the flavor of the course, either during or after the course. The main reason may be due to the fact that when they think of teaching, the lecturers are too concerned about the subject knowledge and not concerned enough about the learners' affective reactions.

In addition to so many negative opinions about the teaching, the majority of the students still regarded the university physics course as worthwhile. This finding implies that most of the students can still see the value of the course; they came to the class not just because it is a compulsory course for their degree. While most of the students agreed that the university physics course was worthwhile, their negative opinions may be interpreted as a wish by the students to make the university physics course become more approachable.

The data discussed above were the combined results of all subjects in seven different classes. The responses to each question by different classes were not consistent; some items were in fact very widely divergent. The next section will discuss the differences among classes.

4.2.2 Teaching style and students' perceptions of the course

Survey 2 consisted of students in seven classes and each class was taught by a

different lecturer. Under the unified policy they were all required to follow the assigned syllabus: to cover the same content topics following the same progress schedule (see section 1.1). However, from the data shown in survey 2, the students' responses to several questions about their perceptions of the course were widely spread. Items that were divergent among classes are shown in the following table.

Table 4.5 Diversity among classes to the perception of the teaching

	Teaching pace too fast	Content very boring	Physics concepts discrete	Content very difficult	Content repetitive
Highest agreement class	85 ^a (3) ^b	73 (7)	70 (10)	61 (8)	48 (18)
Lowest agreement class	38 (28)	24 (48)	28 (47)	21 (41)	19 (41)

^a: agreed percentage, ^b: disagreed percentage

According to Table 4.5, the students' perceptions of the teaching content were widely spread, despite the unified policy.

For the item of pace too fast, the class with the highest agreement showed that 85% of the students agreed and only 3% of the students disagreed, while in the class with the lowest agreement only 38% agreed and 28% disagreed. In the latter class, still more students agreed than disagreed with the fast pace, but the distribution between the two opposing views is not so obvious as in the former.

For the item of content very boring, the two extreme classes' perceptions were almost completely opposite. In the class with the highest agreement, 73% of the students agreed while only as few as 7% disagreed. The students in this class have indicated their consensus of suffering from boredom in their physics class. With respect to the opposing class, in answer to the same question, twice as many students disagreed as agreed. The majority of the students in this class were more likely to enjoy the learning than those in other classes.

Similar diversity among different classes appeared in items of concepts discrete, content very difficult, and content repetitive. For each of these items, the majority

of the students from different classes had completely opposite perceptions of the course.

Two implications emerged from the finding of the divergent perceptions among classes:

(1) Teaching content design is not equivalent to selection of content topics

Although all lecturers have taught the same topics according to the unified curriculum, their students still perceived the pace, the difficulty, the enjoyment of the teaching content and so on very differently. This result indicated that the selection of teaching topics may not be so critical in determining the students' perception of the course content overall. Other considerations such as lecturers' beliefs about the learning process, teaching tasks, and teaching goals of the course may all influence the actual teaching content design (Hodgkinson, 1994). In this research, a complete investigation of the lecturers' opinions about issues relating to teaching content design were also made and will be discussed later in section 5.2. The lecturers' points of view will be compared with those of the students.

(2) Teaching style is crucial to the students' perception of the course

The results of survey 2 showed that the students in each class tended to express similar answers to different questions. For example, the class which expressed the highest agreement that the teaching approach was appealing (class A) also showed the highest agreement that the teaching promoted interest in physics. Class A also had the highest rate of disagreement with the negative stated questions including (1) content was very difficult; (2) content was very boring, and (3) teaching pace was too fast. However, the opposite phenomena was also found in the other specific class (class B). The students in class B expressed the highest agreement, amongst the seven classes investigated in survey 2, to the items of (1) content was very difficult, (2) content was very boring, and (3) teaching pace was too fast, as well as the highest disagreement with the items of attractive teaching approach and teaching promotes my interest in physics.

Each individual lecturer' teaching performance as evaluated by their students has been shown to be fairly consistent for different aspects, such as difficulty, interest, and boredom. On the other hand, significant differences were found from

different classes of students evaluating their lecturers' teaching performance. These results implied that the teaching strategies and the teaching styles were determinant to the students' affective learning outcomes, which is consistent with the literature (eg, Brekelmans, Wubbels and Creton, 1990; Wubbels, Tartwijk and Brekelmans, 1995). Each lecturer's teaching style may be one major reason for the surprising discrepant evaluations when considering the unified policy (see Table 4.5). Meanwhile, the so-called teaching strategy and teaching style may not just be based on their teaching skills, but also on the lecturers' perceptions of teaching and learning (Donald, 1993).

The next step is to investigate how the students' perceptions of different aspects of the course link to each other, and how the students' perceptions of the course link to their learning attitudes and learning strategies. The answers to these questions are approached by calculating the correlation coefficients, and will be discussed in the next sections.

4.2.3 Perceptions of the course and learning strategies

Many studies have indicated the influence of the students' perception of the course on their learning strategies (Kember, Jamieson, Pomfret and Wong, 1995; Marton and Saljo, 1984).

In this section, the researcher is attempting to explore the possible links between the students' perceptions of the course and their adoption of learning strategies and commitments. Pearson product moment correlation coefficients (Beyer, 1968) have been utilized to interpret the links. The results are shown in Table 4.6.

Table 4.6 Perceptions of course and adoption of learning strategies

	Perception of the course					Learning attitudes/strategies				
	too fast	diffi Cult	boring	interest	appeal ing	worth while	concen tration	mini mum effort	regular study	rote learn ing
too fast	1	*0.34	*0.21	-0.11	*-0.22	-0.15	0.01	0.13	0.11	0.10
difficult		1	*0.45	*-0.25	*-0.20	*-0.20	-0.11	*0.30	0.08	0.05
boring			1	*-0.43	*-0.47	*-0.34	*-0.24	*0.36	0.02	0.05
interest				1	*0.34	*0.42	*0.23	*-0.32	-0.02	-0.11
appealing					1	*0.22	0.16	*-0.23	0.07	0.00
worthwhile						1	*0.20	*-0.39	-0.11	-0.05
concentration							1	0.03	0.15	-0.15
minimum effort								1	-0.06	0.12
regular study									1	0.00
rote learning										1

Note: The critical value of correlation coefficients is 0.195 at $p < 0.01$ in two tail test (Beyer 1968).

* indicates significantly correlated at $p < 0.01$.

Three points relating to the correlation coefficients shown above are discussed:

(1) Relations among items in the students' perceptions of the course

From the results in Table 4.6, the five items concerning the students' perceptions of the teaching were significantly correlated to each other at the $p < 0.01$ level. The feelings that the teaching was too fast, very boring, and very difficult were significantly positively correlated. Also, these three negative statements were significantly negatively correlated to the other two positive statements: teaching approach was appealing and promoted interest in physics. The significant links implied that the students perceived the aspects of teaching, such as teaching content, and teaching approach, as a whole rather than as separate components. Also, different types of perceptions such as pace, difficulty, and enjoyment may be confused in the students' minds. The general perceptions about the course may determine the students' attitudes to learning the course.

(2) Relations between perceptions of the course and adopting learning attitudes

According to the data shown in Table 4.6, several learning attitudes seem to have strong links to the students' perceptions of the teaching. Comparing the five items concerned with teaching, feelings of boredom, interest, and appeal appear to be more closely linked to learning attitude than feelings that the course is too fast and difficult. The feelings of boredom, interest, and appeal belong to the affective

aspect, while the other two perceptions, too fast and too difficult, relate to the cognitive aspect. The results indicate that the feelings of interest and boredom have greater links than the feelings of too fast and too difficult to some learning attitudes, including: (a) the course is worth studying; (b) concentration in class, and (c) expected to put in minimum effort to pass only. This implies that the affective outcome of teaching can have an important impact on the learners' attitudes, and can influence the learners' adopted learning strategies. This result highlighted the affective responses in promoting learning motivations (worthwhile) and commitment (concentration and avoiding minimum effort). The students will be more likely to have a positive learning attitude and possess stronger learning motivation if they have experienced enjoyment during the learning process.

The above assertion is in accordance with White *et al.*'s (1995) study. They found that the students appeared to be more concerned with affective factors than with cognitive considerations when they responded to the survey of their perceptions about learning university physics. They also argued that affective consideration is of little concern to most lecturers.

In this research, the students' opinions have indicated the importance of the affective outcomes, and the lecturers' perspectives will be discussed in the next chapter (see section 5.5.3).

It should be noted here that, according to Table 4.6, four items out of the five in learning attitudes and strategies are ^{statistically} significantly linked to the perception of the course, while one item has very low correlation coefficients with all items in teaching. The item that appeared to be independent of the features of the course is learning by rote. This exception may be caused by the assessment design, which is discussed as follows.

(3) Role of assessment in determining learning strategies

The unified examination and the orientations of assessment may be the major reason for so many students adopting rote learning, and may also explain why they are not influenced by their lecturers' teaching style.

According to survey 2, the adoption of rote learning strategies was found to be

prevalent (about 80%) amongst all classes as well as independent of different teaching styles and strategies, according to the non-significant correlation coefficients. The features of the course presented by individual lecturers appeared to have little influence on reducing the high percentage of the students adopting a rote learning strategy. With such consistent and high percentages of students adopting a rote learning strategy, the design of the assessment may need to be greatly adjusted to guide the learners to abandon rote learning and encourage adoption of a comprehension learning approach. This result implied that the assessment orientation has a stronger impact on the students than the emphasis in teaching in determining what learning strategies are more effective. The existing assessment design is more likely to enhance than discourage students' commitment to rote learning.

In summary, the above discussion has indicated (1) the links between teaching styles and students' affective responses, (2) the importance of the students' affective responses to the course in determining their learning motivations and attitudes, and (3) the assessment orientations in determining learning strategies. The above discussion was based on survey 2. More details were investigated in survey 1S about ways to promote the learners' interest, and the effects when the learning interest is promoted. The results will be discussed in the following section.

4.2.4 Learning interest: possible causes and effects

To further understand the factor of learning interest in influencing the learning outcome, and reasons to determine the learning interest in physics classes, the results of survey 1S may provide some clues. Based on the correlation coefficients, the importance of learning interest emerged in survey 1S as well as in survey 2, as mentioned in section 4.2.3.

To illustrate the results of survey 1S, three steps are described below:

- (1) the productive effects of learning interest in learning outcome,
- (2) reasons to determine learning interest,

(3) perceptions of work load.

(1) The effects of learning interest

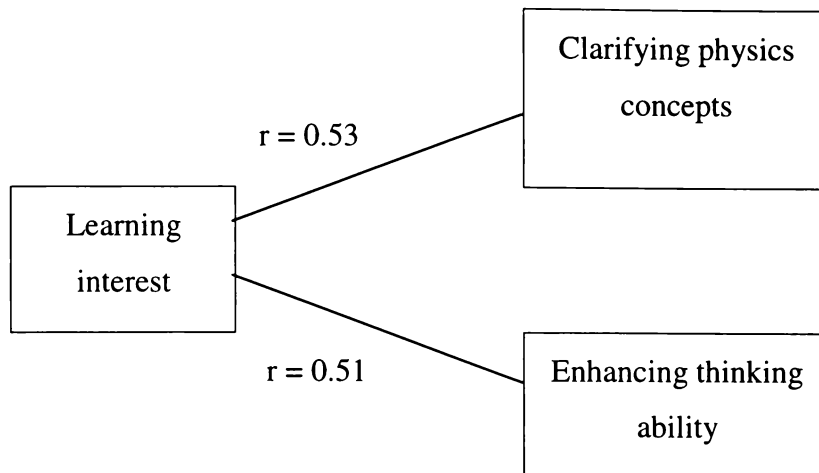


Figure 4.6 The effects of learning interest

According to the correlation coefficients, learning interest is shown to be strongly positively linked to enhancing thinking ability and clarifying physics concepts. These two outcomes are regarded by the physics lecturers as the most important teaching goals of the university physics course (see section 5.2.2).

Amongst all factors, the links between learning interest and enhancing thinking and clarifying concepts are the highest. From the correlation coefficients, learning interest was the most important factor in clarifying the learners' understanding of physics concepts. It was more strongly related than all the other factors of teaching skills/ techniques in clarifying concepts. The correlation between learning interest and clarifying concepts was $r=0.53$. It was much higher than that between clarifying concepts and the excellence of the lecturers' subject knowledge ($r=0.19$) and presenting lucid lectures ($r=0.23$) (see Figure 4.7). This implies that teaching skills and performance are less important than the learners' interest in determining the learning outcomes. Although the lecturers have a strong background in subject knowledge and even give lucid lectures, without the learners' interest, the learning outcome is hardly going to be satisfactory.

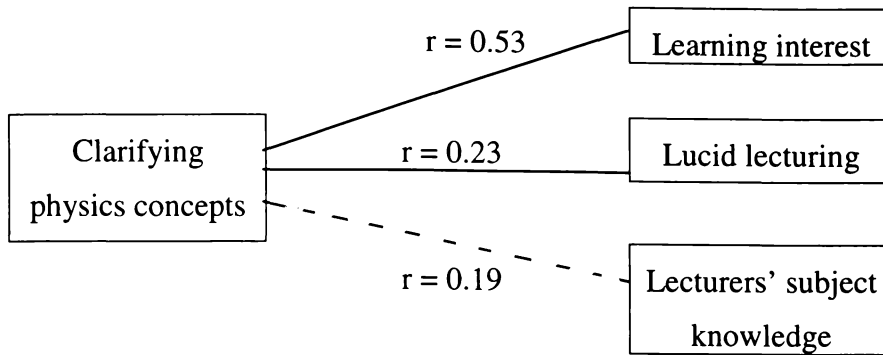


Figure 4.7 Factors linked to clarification of physics concepts

Noted: dashed line indicates non-significantly correlated at $p=0.01$ level

This result supports the discussion in section 4.2.3 that learning interest is not just beneficial, but essential to learning outcome. While most of the lecturers focus on their teaching in class, they need to be aware of the existence of the affective consideration.

When claiming the importance of learning interest, the researcher did not attempt to regard the factor as independent. As mentioned in section 4.2.2, learning interest may be closely related to the teaching style and the learners' perceptions of the course. Possible ways to influence learning interest are discussed next.

(2) Ways to influence learning interest

Several factors may influence learning interest. Factors of teaching style that were significantly correlated to learning interest at the $p<0.01$ level are shown in Figure 4.8.

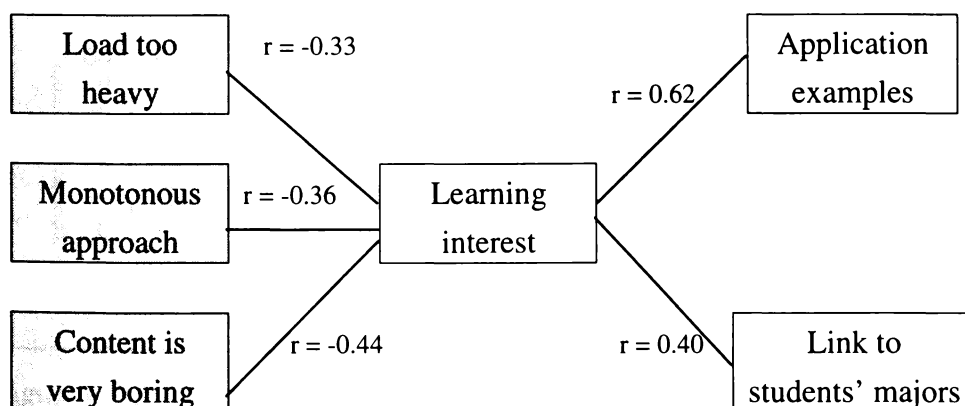


Figure 4.8 Factors significantly correlated to learning interest.

Noted: Each pair is significantly correlated at $p<0.01$. Shaded items indicate significantly negatively correlated items to learning interest.

According to Figure 4.8, many factors in teaching may influence learning interest. In teaching content design, providing application examples to link physics to everyday life, and introducing topics related to the students' major are regarded as beneficial to promoting learning interest. Therefore, showing the relevance, either to the students' career or to their everyday life is a good approach. Lack of relevance may cause the learners to feel that the content is boring and may also reduce learning interest. Meanwhile, perception of the workload as too heavy can reduce the learning interest. More details about the students' perception of the workload will be discussed in the next section.

The other factor which may reduce learning interest is a monotonous teaching approach based on traditional didactic teaching. In order to promote the learners' interest, the didactic teaching approach needs to be modified in order to encourage the learners' participation in the learning process.

4.2.5 Teaching time and students' perceptions of workload

According to the literature, constraint of lecture time is usually regarded as a main barrier to improving learning outcomes. In this research, a comparison of classes with two different lecture hours: 3 hr/wk and 2 hr/wk was made to obtain a better understanding of the impact of teaching time constraints on the learners' perceptions of the course, and their learning outcomes. The results are shown in Figure 4.9.

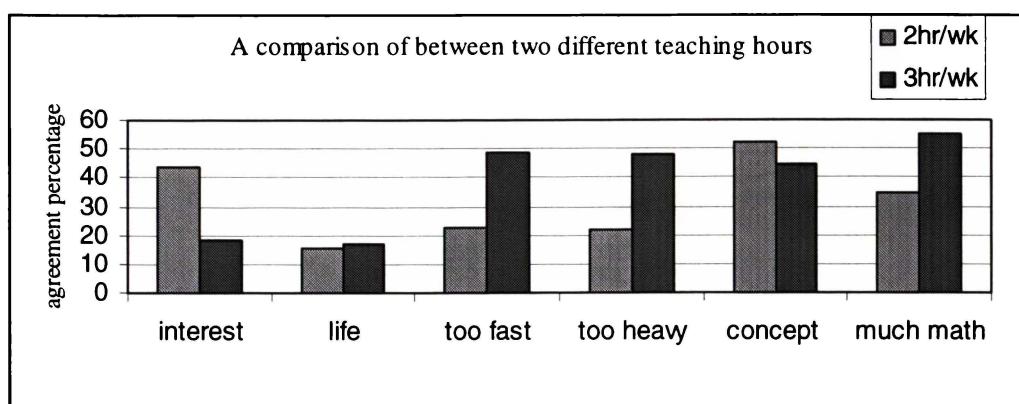


Figure 4.9 A comparison of students' perceptions between two different teaching hours.

The students in 3 hr/wk classes expressed stronger criticisms of (1) too much

math, (2) pace too fast, (3) load too heavy, and (4) lack of interest, than the opinions of the 2 hr/wk classes. Comparing to those of 3 hr/wk, the students with 2 hr/wk agreed less that the pace was too fast, and the workload was too heavy, but agreed more with promoting interest and clarifying physics concepts. A surprising result showed that the classes with fewer lecture hours expressed more positive opinions not only regarding the course design (eg, interest, reasonable pace and workload) but also their learning achievements (physics concepts).

Since the data included only three classes of 3 hr/wk and two classes of 2 hr/wk, the result may not be sufficient to make any firm conclusions about the role of lecture time in curriculum design. However, the result may imply that the limitation of lecture time is not an insurmountable excuse for unsatisfactory teaching.

Possible reasons for the surprising results are elaborated on by the students' perceptions of the workload.

Possible factors influencing the students' perceptions of workload are evaluated by the correlation coefficients. From the results shown in Figure 4.10, the students' perceptions of the workload seem to be only loosely linked to the actual amount of required work. The perception of a heavy workload was consistent with the perception of teaching pace too fast, and too much mathematics. However, the perception of a heavy workload mismatched achievement in understanding the physics concepts.

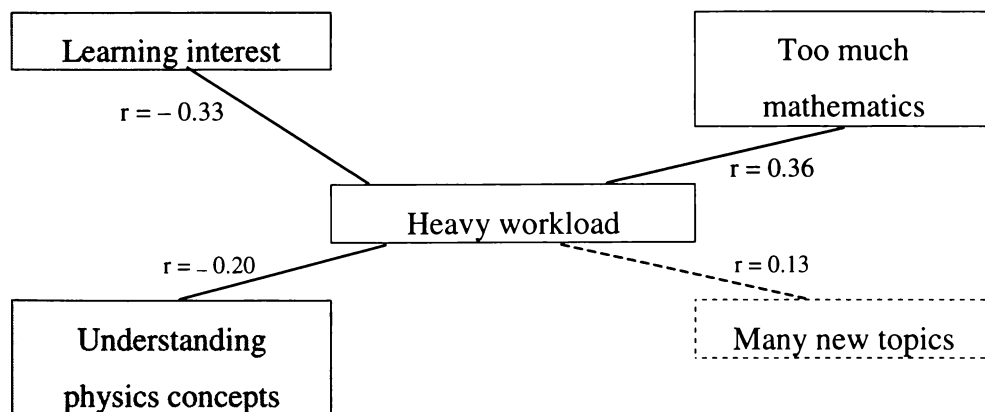


Figure 4.10 Factors linked to perceived heavy workload

Noted: Dashed line indicates non-significantly correlated at $p=0.01$ level, and shaded items indicate negatively correlated.

According to Figure 4.10, too much mathematics may be the main cause of feelings of a heavy load. The perception of a heavy load is shown to be the highest amongst all factors correlated to introducing too much mathematics ($r=0.36$); it was even higher than introducing more topics ($r=0.13$). On the other hand, the effort put into understanding physics concepts seemed not to create but to reduce the feeling of a heavy workload ($r=-0.20$). Practicing mathematics and clarifying physics concepts appeared to be two opposing factors in relation to the students' perceptions of workload. The students' favorable attitudes towards learning physics concepts may be related to their perceptions of the goals of the course, ie, the students placed more value on developing their understanding of physics concepts than on enhancing mathematical skills from learning university physics (see section 4.1.1).

At the same time, the results imply that the perception of a heavy workload may deteriorate learning interest ($r=-0.33$) and slightly hinder the learners' understanding of physics concepts ($r=-0.20$).

Concluding from the above statements, the students' perception of the workload may be very different from the work they have really done. The students may work very hard on learning physics without perceiving the workload to be very heavy or hard, when they feel interested in the learning process and/or feel that it is valuable, while vice versa is also true. This finding highlighted the consideration of learners' affective dimensions and beliefs of the goals of the course in the learning process, which supports the researcher's thesis.

4.2.6 Summary

To summarize the above five sections' discussion of the students' perceptions and evaluations of the university physics course, five points can be made:

- (1) Most of the students were not satisfied with the overall existing teaching of the course. The major problems included pace too fast, content irrelevant, and monotonous teaching approach, which were more significant than the difficulty of the course.
- (2) The students' perceptions of the course were widely spread with respect to

different classes with different lecturers; teaching style and design may be crucial to determine the students' perceptions of the course.

- (3) The students' evaluations of the course, particularly in affective aspects, can be critical in determining their learning motivation and commitment, while assessment orientation may dominate the students' learning strategies.
- (4) External constraints such as teaching time limitation and assigned syllabus may not be so crucial and insurmountable for achieving satisfying learning outcomes, both cognitive and affective.
- (5) Learners' motivational considerations including affective reactions and beliefs of the goals of the course may influence their perceptions of the workload and learning outcomes.

In this section, the students' responses to the closed questions evaluating the existing teaching performance and their learning have been discussed. The next section discusses the students' comments and suggestions in the open-ended questions with respect to the current teaching design.

4.3 Evaluation of the course: Results of open-ended questions

This section presents a qualitative analysis of the students' responses in regard to the current teaching. The students were asked three open-ended questions at the end of the questionnaire in survey 2 including (1) the major weaknesses, (2) the major strengths, and (3) comments on the existing course. Details about the questionnaire design were described in section 3.3.2.

In total, 330 students answered survey 2. Over half of the students gave one or two answers to each open-ended question, about one third of them only answered one to two of the questions and less than 5% of the students did not respond at all to the open-ended questions.

The results of the open-ended questions were then analyzed by grouping similar

statements into one item, and counting the total responses for each item. Since the students' responses to the third question: comments about the course overall, overlapped with those of the first two questions, the results were analyzed together. Items with fewer than five students responding were regarded as minor concerns amongst all students, and these opinions are omitted in the following discussion.

The students' opinions will be discussed in three parts:

- (1) major weaknesses and strengths of the course,
- (2) how good or bad is the course, and
- (3) suggestions for modifying current teaching.

4.3.1 Major weaknesses and strengths of the course

The students' responses to which features of the course they liked or disliked, i.e., the strengths and weaknesses as perceived by the students, were often combined with their suggestions for improving the teaching and learning. These opinions can provide clues to the students' views of the ways to improve the course. The results are listed in Table 4.7 in the order of responding frequency. Several items include two opposing opinions, such as teaching was boring/interesting, being ir/relevant to life, too difficult/easy. The major opinions are given in the table with their responding frequencies, and the frequencies of the opposing opinions corresponding to the listed statements are also listed in the brackets.

Table 4.7 Students' perceptions of the course: the strengths and the weaknesses

order	Students' statement	Weakness(W) /strength (S)	Number of students
1	Teaching pace was too fast	W	87
2	Teaching was very boring	W	74 (15) ^a
3	No relevance to life	W	47 (6)
4	No relevance to major courses	W	24
5	Lecturer works hard on teaching	S	20
6	Too difficult (too easy)	W	24 (6)
7	Lack of interaction	W	12
8	Content was repetitive	W	9
9	Better understanding of concepts	S	9
10	English-version textbook needs to be changed	W	10(3)
11	Topics need more integration	W	7
12	Teaching unsystematic	W	6 (1)
13	The students did not concentrate	W	5

^a: The numbers indicated in the brackets are the number of students who expressed opposite opinions to the corresponding statements.

According to Table 4.7, the top five comments were: (1) teaching pace was too fast; (2) teaching was very boring; (3) teaching content was not relevant to life; (4) content was not relevant to major courses, and (5) lecturers showed high teaching commitment. The order of the students' main concerns based on the open-ended questions were similar to their responses to the closed questions which were discussed in section 4.2.1. Since the open-ended questions followed the closed questions, the closed questions may have provided some hint and/or guidance for the students answering the open-ended questions.

More details of the results given in Table 4.7 are discussed along with some corresponding quotes in order to clarify the students' perceptions of the course.

- ***Too fast and too difficult***

Teaching pace too fast was the highest concern (suffering) for the students. As

many as 87 students noted the weakness of an unreasonable teaching pace and/or content coverage. No opposite opinions were found. The following quotes illustrate their concerns about the teaching pace:

(We) just keep copying the notes, no time for thinking!

The course could be much better if the content coverage could be drastically reduced.

Teaching content includes too many topics, teaching pace is too fast, and the unified examinations cover too much. (We have) no time to seek for understanding.

Learning university physics in one year is mission impossible! A conclusion of many senior students.

Based on the above quotes, the complaints about the teaching pace were often accompanied with comments about content coverage. However, the problem of teaching too fast seemed to be independent of feelings of difficulty.

There were only 24 students who noted that the course was too difficult, and six claimed that the course was too easy. This issue was rated sixth amongst all the issues. The responses of feelings of difficulty were much less than feelings of too fast, very boring and irrelevant. From the frequency order listed in Table 4.7, perhaps the students did not learn well, not because the course was too difficult, but because the course was taught too fast, too much was taught, and what was taught was irrelevant and too boring. This result was consistent with the results of the closed questions discussed in section 4.2.1. Some quotes illustrate the students' feeling of the course being too difficult/easy!

The subject (physics) is very difficult for me.

This course has made me suffer the most; physics is my nightmare!

Most of the content is a repetition of what we have learnt in high school. The level is too easy for those students who really want to learn something new.

Due to the diversity of the students' backgrounds in physics, it is unlikely that a standard to match the learning ability of all the students could be found. A better way to solve this problem may be to provide a flexible assessment policy and give a certain degree of flexibility to the students to match the ability of each

individual. However, this kind of adjustment may conflict with the consideration of fairness and is very challenging to the traditional administration policy. Before such flexibility can be practically implemented under the unique-standard of the curriculum design, the difficulty of the course can be regarded as a minor concern compared with other issues.

- ***Feeling of boredom and lack of interaction in teaching***

The second highest concern of the students was the feeling of boredom. Up to 74 students pointed out that they felt bored in the physics class, and only 15 students noted that the teaching was interesting or appealing. Some quotes illustrate the students' suffering of boredom:

Boring! I feel the university physics course not only does not stimulate my interest in physics but even reduces it; the professor has no interaction with us.

Quite boring! Very boring! Certainly, the course is too boring!

I wonder if our physics professor has learnt hypnosis; it is so easy to feel sleepy in his class.

Boring, the tone of the professor is too dull.

The teaching is very VERY (emphasized by the student) boring, and I don't know what the main concepts are.

Too boring, makes me feel like ZZZ...

Boring! Newton's brilliant discovery results in my suffering (in learning this subject)!

With respect to the class distribution, the students' complaints of boredom appear to be divergent amongst different classes. While most of the classes strongly criticized the boredom, one class (class A) appeared to be very positive in the area of learning interest. In class A, twelve students noted that the teaching was interesting or vivid, and only three students gave opposing responses. This result supports the previous assertion, discussed in section 4.2.2, that individual teaching style is crucial to the learners' interest.

Feelings of boredom in physics classes can be caused by many factors. Teaching style/approach may be one of the major reasons according to the above quotes.

Other possible reasons may be problems in content design, e.g., too fast, irrelevant. Based on the students' responses, a didactic way of teaching which is lacking in interaction between lecturers and students seems to have a stronger link to the feeling of boredom than other factors.

Twelve students responded that there was a lack of interaction in class. For example:

The teaching needs to be more interactive.

The professor should have more interactions with the students (while teaching), then he can understand our learning progress.

In phase 3 of this research, possible ways to reduce the feelings of boredom and an attempt to promote interaction in class were investigated by implementing the intervention teaching program. The outcomes of the program will be discussed later in chapters 8 and 9.

- ***Showing relevance to life and career***

The third and fourth significant features of the course perceived by the students were that the course did not have any relevance to their everyday lives or future careers. Forty seven students pointed out that the course was lacking in links to the real world, and only six students held an opposing view. Also, 24 students complained that the course design did not correspond to their majoring courses. The examples of lack of relevance are:

(The course) needs to provide some links to our major (courses).

The course design is for students in the 18th century.

(The course is) too old-fashioned; (we) need more contemporary topics.

Nonsense! The course is not practical at all.

The only hope I have is to make this course more practical and not so theoretical.

Too much emphasis on theory makes me feel sleepy.

(The course) should introduce more application examples linked to everyday life.

As the quotes above illustrate, lack of relevance may make the learners doubt the value of the course. Feather (1982) proposed an expectancy-value theory in dealing with learning motivation. He noted that if learners are to engage in an activity, they need teachers to help them see the value of what they are doing as well as give a reasonable expectation of success in achieving it.

Therefore, only when the students can feel the value of studying the course can they be devoted to the learning process. Showing relevance to life and/or career is one way to address the value of the course. The lecturers may need to put more effort into searching for more practical information to accomplish this teaching goal in practice.

- ***Highly devoted lecturers along with low engaged students***

Twenty students pointed out that the lecturers have shown high teaching commitment. However, five out of the 20 students also mentioned the problem of low engaged students in contrast to their praise of the highly committed lecturers. Some quotes illustrate this feature of teaching commitment:

I can feel that our professor has put much effort into his teaching.

Our professor had shown a sincere concern about the teaching.

The professor works hard on teaching, but I just cannot understand (what he teaches).

The professor works very hard in teaching, but the students just pay too little attention to it.

According to these quotes, the students may appreciate the efforts that the lecturers put into the teaching on one hand, but feel dissatisfaction about the teaching outcomes on the other. From the students' quotes, the main feature of the teaching commitment was limited to the teaching task of transmitting knowledge rather than the teaching task of engaging students in learning. Although some students have expressed their appreciation of the lecturers' efforts in the teaching work, there is little evidence to show that this commitment has links to achievement in learning. This implies that highly committed lecturers may still possibly have low engaged students when the lecturers pay no attention to the learning process.

- ***Content repetitive along with better understanding of concepts***

Nine students regarded the fact that the teaching content was a repetition of high school physics as a major weakness of the university physics course, and also nine other students pointed out that the strength of the course was to help them enhance their understanding of the concepts. For example:

The course is almost the same as what we have learnt at high school, and even simpler than what we learnt at high school.

I have a better understanding of the physics concepts (at university) than I had at high school.

The teaching content in university physics and in high school physics overlap to a certain degree. However, overlapping of content topics may result in two different comments. One is to feel that the course at university is repetitive and results in dissatisfaction due to learning nothing, while the other may regard it as providing a second chance to clarify understanding of concepts. The results showed that the two opposing groups of people were balanced. As discussed in section 4.2.2, the discrepant teaching styles amongst different lecturers may explain the balance in the opposing opinions about the repetition of teaching content.

- ***Lack of integration amongst concepts and systematic teaching***

Seven students pointed out that there was a lack of integration amongst concepts, and six answered that the structure of teaching was unsystematic. For example:

All materials we learnt appear to be trivial and discrete. The lecturer should teach us more about the links among them.

The teaching has no system, I have no idea about what the key points are after each class.

From the above quotes, lack of integration and structure may make the students feel that it is difficult to organise the main ideas of the lesson, as well as make links between a wider domain of concepts. According to Marton's (1975) notion, searching for the key points and integrating among concepts are regarded as deep-level learning. However, from the above quotes, the students have a passive attitude and are waiting for the lecturers to do the job for them. The lecturers need to realize the importance of these two learning tasks, and encourage the learners to try integrating concepts and summarizing key points on their own.

To conclude from the results in Table 4.7, one feature may be frustrating to all the lecturers. The negative responses were much more than the positive, although the researcher asked for both strengths and weaknesses in the questionnaire. Within the thirteen high-response statements, only two items can be regarded as strengths, while the other eleven items are weaknesses of the course. The only two positive responses are: Lecturers work hard at teaching, and better understanding of physics concepts.

The students seemed to focus more on the negative side than the positive side of the course. More details about how good or bad the students felt the course was will be discussed in the next section.

4.3.2 How good or bad is the course?

According to the above findings, the students seemed to possess more criticisms than praise for the course overall. To better understand the proportions of the two opposing parts, a count of the frequencies was made. All responses were categorized into three groups: strength (S), weakness (W), and neutral or irrelevant comments (N). Some quotes to illustrate the categorization are as follows.

The professor is friendly and approachable. (S)

The teaching is vivid and interesting. (S)

(Studying) the course is worthwhile. (S)

The professor teaches hard but the students are careless. (N)

The professor gives grade generously/ too strict. (N)

The textbook is too heavy and too expensive. (N)

The examinations force us to do rote learning. (W)

The course is useless. Change it (from compulsory) to optional. (W)

The distribution of the students' responses with respect to the three categories are listed in the table below.

Table 4.8 Responding frequencies of the students' evaluation of the course

Categories of comments	Frequency
The strengths	126
The weaknesses	381
Neutral/ irrelevant opinions	93

From the results shown in the table, the frequency of comments related to the weaknesses of the course are more than three times that of the strengths. In addition, there were 26 students who claimed that no strengths were found, and only 9 students noted that there were no weaknesses when commenting on the course overall.

The results of the open-ended questions strongly indicate the students' dissatisfaction with the course and also imply that a modification to the teaching design of the university physics course is highly necessary. Nine students mentioned specifically that they expected to see an improvement in the course design. For example:

The course is ok, but I think there is still a big space for it to be improved.

Based on the students' comments, suggestions for modifying the current teaching design will be discussed as follows.

4.3.3 Suggestions for modifying current teaching

To summarize the students' responses about the course in the open-ended questions, the major problems of the course design include (1) the unreasonable teaching pace, (2) lack of relevance, (3) feeling of boredom, and (4) lack of interaction in class.

The students' responses provided clues for curriculum innovations, suggestions for modifying the course design are:

- (1) reduce the teaching content coverage to match with the learning pace,
- (2) provide more information to link the physics theory to the students' life and majors, to show the relevance of this course in practical usage,
- (3) encourage and promote interaction between the lecturer and the students, and abandon the traditional didactic teaching approach.

These suggestions implied by the students' responses are in accordance with many articles by physicists (eg, Gordon and Aubrecht, 1989; Redish, 1996). These suggestions were adopted by the researcher when designing the intervention teaching program. In phase 3, the researcher implemented the intervention program, and the students' evaluations of the new design were investigated. The results will be discussed in chapters 8 and 9.

Sections 4.2 and 4.3 have discussed the students' evaluation of the course overall.

While most of the students held negative perceptions of the course, many of them seemed to still appreciate the effort that their lecturers put into the teaching. The next section investigates the students' perceptions of their lecturers' ability and performance.

4.4 Physics lecturers and teaching performance

In this section, two main research questions will be discussed:

- (1) The students' expectations of the lecturers: which kinds of ability should a good physics lecturer be equipped with, and what teaching approaches are mostly expected in the teaching?
- (2) The students' evaluation of the lecturers: how did the physics lecturers perform in class?

Details about the questionnaire design were discussed in the methodology chapter in section 3.3.2.

The students' expectation priorities and their evaluation of the lecturers'

performance will be discussed in the following two sections.

4.4.1 Students' expectations of a good physics lecturer

In survey 1S, all subjects were second year students who had just completed the university physics course. To understand what ability and approach the students most expected from their physics lecturers, the students were asked to rank the six selected items.

Figure 4.11 shows the priority given to each student's top two ranked items. The items ranked in the top two were counted and are expressed as a percentage rating.

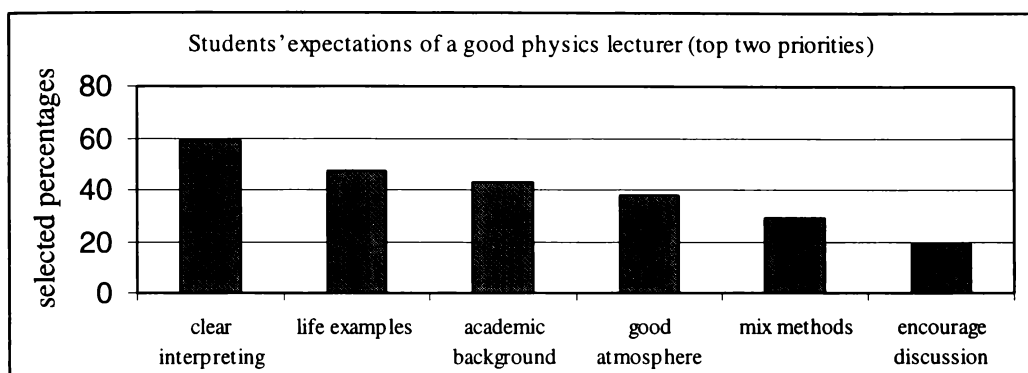


Figure 4.11 Students' expectations of a good physics lecturer

The results showed that the three most important features students expected of a good physics lecturer were (1) to be able to articulate the concepts, (2) to provide examples linking physics theory to everyday life, and (3) to be equipped with strong knowledge background in the subject. These three statements are specifically limited to the lecturers and their teaching performance, rather than linked to students' learning engagement. In contrast, the other items with lower importance expected by the students of their lecturers are those more directly linked to learning engagement, those are, cultivate good classroom atmosphere, adopt a mix of teaching methods, and encourage discussion.

The students' expectations of their physics lecturers may have resulted from their experiences of the traditional style of teaching where the major teaching task is limited to transmitting knowledge. Also, a learner in a traditional class has been mainly limited to being a passive receptor. Under this perception of the teaching style, the ability of interpreting information, the teaching material, and academic

background were perceived to be crucial for lecturers.

From their responses, it can be postulated that the students may not expect themselves as learners to engage much in class activities. Teaching effort to promote the engagement of the students in the learning process, such as providing a good classroom atmosphere, encouraging discussion, and adopting alternative teaching methods, were regarded as trivial. The students seemed to have no objection that lecturers can focus on their own teaching material and skill of interpretation rather than be concerned about the learning process.

The students' expectations tended to limit the teaching task to transmitting knowledge, and engaging in learning seemed to be merely auxiliary.

In summary, the students' responses appeared to agree with the existing teaching design; their agreement, however, mismatched those of the education researchers who emphasize the crucial role of the learners being intellectually active and participating in social practice in the classroom (eg, Bell and Gilbert, 1996; Roth, McRobbie, Lucas and Boutonne, 1997). In Roth, McRobbie, Lucas and Boutonne's, (1997) study, they found that without providing chances for the students to express and evaluate their understanding of the concepts, the students may fail to capture the concepts that the teacher has expected them to learn through oral interpretation as well as demonstration.

4.4.2 Satisfaction with teacher/teaching

In addition to the students' expectations of what constitutes a good physics lecturer, the students' evaluations of the lecturers' performance in teaching were also investigated in the same survey (survey 1S). The students were asked to select amongst the five-likert scales to express their opinions about the lecturers' performance. The results are listed in Figure 4.12. The percentages of agreement included both completely agree and agree, as do the disagreement percentages.

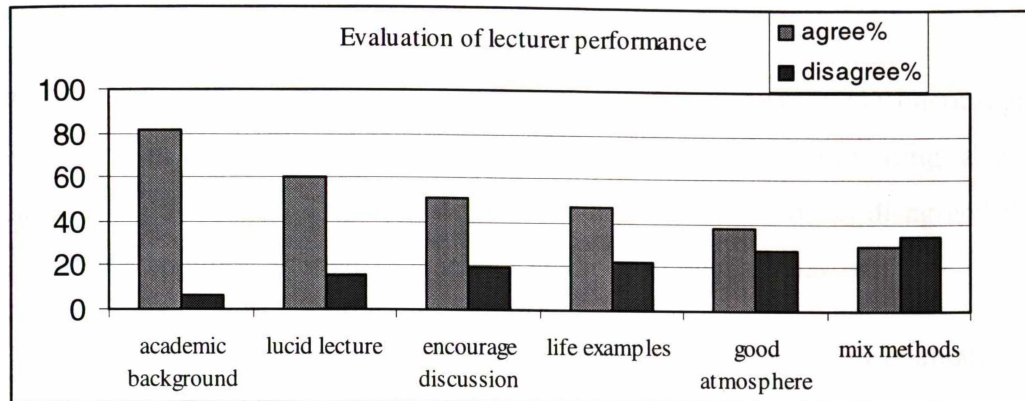


Figure 4.12 Evaluation of lecturer performance

- **Results overall**

In general, the students gave quite positive responses when evaluating the lecturers' ability and teaching performance. More students agreed than disagreed with all of the six items, except for applying alternative teaching methods. The students seemed to be satisfied with their lecturers' performance, in contrast to high dissatisfaction with the course and with their own learning achievements (sections 4.2.1 and 4.3.2). The paradox may be caused by the students' appreciation of the effort that their lecturers have shown in teaching (see section 4.3.1); but the teaching outcomes did not appear to match the teaching effort. These contrastive perceptions of the lecturers and the course were found in the responses to the closed questions as well as in the open-ended questions. One student commented in the open-ended questions:

The professor is good, the curriculum is bad, and the learning (achievement) is even worse!

- **Major strengths of the lecturers**

Among the six items related to the lecturers' ability and performance, the most significant strength of the lecturers as evaluated by the students was their academic background in physics. Over 80% of the students agreed and only 6% disagreed that their lecturers were equipped with strong academic backgrounds in physics. The response is reasonable since academic qualifications are a fundamental requirement for being a lecturer.

The next significant item evaluated by the students was that the lecturers gave lucid lectures. Around 60% of the students agreed and only 16% of the students

disagreed that their lecturers have given lucid lectures in class.

Items that were not so strongly positive as the top two were (1) encouraging discussion in class, (2) providing life examples, and (3) cultivating a good classroom atmosphere. The only item where a few more students disagreed than agreed was applying alternative teaching methods in physics classes.

The ranking of agreement between the students' expectations and evaluation of the lecturer was fairly consistent. This means that what the students regarded as the most important factors for a physics lecturer matched what significant strengths they evaluated in their lecturer performances, and vice versa. For example, academic background was perceived to be the most important factor for being a good lecturer, and also gained most of the students' agreement when evaluating their lecturers' performance. The lower ranking of providing a good atmosphere, encouraging discussion, and applying alternative teaching methods should not, of course, be interpreted as dissatisfaction with the lecturers' performance overall since these three items had a less important expectation ranking by students. The three items are beyond the scope of the traditional transmission way of teaching, and therefore the students seemed to have thought less about a new teaching approach than the traditional approach.

The consistency between the expectations and evaluation of the students' perception of their lecturers' performance may result in a positive comment about the lecturers and their teaching. The satisfaction with the existing teaching performance may also indicate that students did not see anything wrong with the traditional didactic way of teaching. However, many educators have argued against the effectiveness of the didactic ways of teaching and have emphasized the crucial role of engaging the learners in the teaching process (eg, Bell B., 1993; Duit and Treagust, 1995; Linder and Erickson, 1989; McDermott, 1993). The students' satisfaction with the traditional teaching approach may become a barrier for adjusting the traditional teaching model to an approach, which attempts to promote more engagement of the learners in the learning process (Roth and Roychoudhury, 1994).

This section has dealt with the students' expectations and evaluations of lecturers.

The students' perceptions of their own learning were also surveyed in this research. The results will be discussed in the next section.

4.5 Self-expectation and self-assessment of the learners

In this section, the students' perceptions of their own learning are discussed. Four points are discussed in sequence:

- (1) original learning attitudes,
- (2) a mismatch of expectation and behavior in learning,
- (3) learning barriers, and
- (4) academic background in physics.

4.5.1 Original learning attitudes

The students' original learning attitudes and their expectations towards the new stage of learning at university were investigated in survey 1F of the incoming students. The considerations and design of the questions are described in section 3.3.1.

The results of the incoming students, original expectations, their learning attitudes and strategies are listed in Figure 4.13.

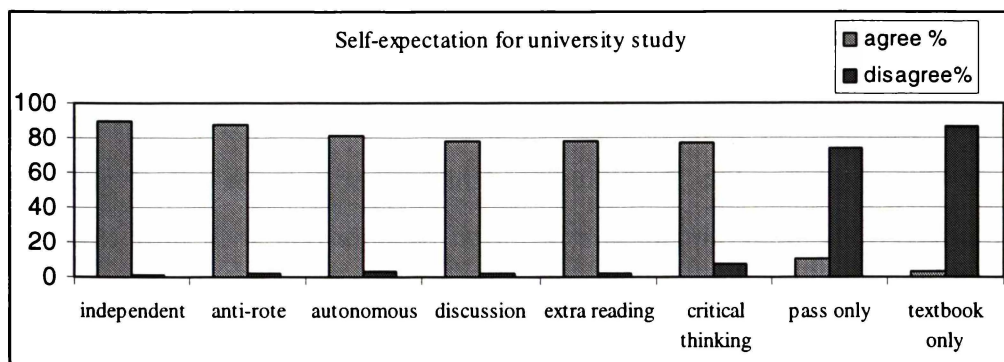


Figure 4.13 Original self-expectations of learning attitudes and learning strategies

The data in Figure 4.13 shows that most incoming students possessed high self-expectations regarding university study. More than 80% of the students expected

to (1) be equipped with the required ability of an independent learner, (2) avoid rote learning and search for a better understanding of the concepts, (3) become autonomous and self-disciplined in future study.

For the negative statements, only 11% of students responded that they did not intend to put in more than the minimum effort required to pass the course, and 74% of the students disagreed with this narrow perspective. Meanwhile, about 80% of students disagreed that university study is limited to reading textbooks, and expected to have a wider scope of reading to develop their knowledge.

The results strongly indicated that most of the students held high expectations regarding university study, not just for earning a degree but for developing their intellectual capacities and knowledge. The positive original learning attitudes reported by the students were also compared with the students' self-assessment of their actual effort and learning approach while learning university physics.

Results of the comparison between the students' original expectations and their actual learning commitments will be discussed next.

4.5.2 A mismatch of expectation and behavior in learning

In this section, a comparison is made between the students' original expectations before studying the course and the self-assessment during and after studying the course is made. Students' original expectations were investigated in survey 1F and survey 3A, and their self-assessments were made in survey 2, and survey 3B. The design of all these surveys is described in detail in sections 3.3.1 and 3.3.2.

The students' original expectations gave cause for optimism. Unfortunately, according to the results the students' original high self-expectations were not consistent with their performance during the academic year. The original high expectations of the students regarding their own learning, both in learning habits and learning approach, seemed to be unable to be put into practice. A mismatch between their expectations and actual implementation emerged.

The mismatch between the learners' expectations and implementations can be discussed in relation to four points: (1) willingness of attendance, (2) minimum

effort for pass only, (3) study hours out of class, and (4) memorizing formulas without understanding.

The results are listed in Table 4.9 and are discussed below.

Table 4.9 A comparison between students' original expected learning attitudes and actual implementation.

	Attendance	Minimum effort to pass	Memorising without understanding	Study hours out of class
	Agree % (Disagree %) ²			>4 (= <1) Hrs/wk
Expectation	87% (0.5%)	11% (74%)	2% (89%)	59% (3%)
Implementation	75%(12%)	31% (40%)	79% (9%)	21% (37%)

(1) Willingness of attendance

The first indicator of students' learning attitudes is their willingness of attendance. In survey 3A, as low as 0.5% of the incoming students expected that they would attend the physics class just for calling the roll. However, in survey 3B, just three weeks later, the percentage of students who responded that they would attend the physics class purely for roll calling had drastically increased to 12%. This indicates that the early learning experience of a significant number of these students was so negative that it had actually diminished their original positive learning motivations. This deterioration also provides a clue to the high failure rate of the course.

(2) Minimum effort to pass

The second item regarding students' learning attitudes is the intention of putting in minimum effort to pass only. If some students do have such expectations of their university study, they are more likely to limit their effort to merely avoiding failing.

² In addition to responses of agreement and disagreement, there was also a neutral alternative. Therefore, the sum of the percentages of agreement and disagreement was less than 100%.

The results of survey 1F show that 11% of the students agreed and 74% disagreed that they would not put more effort than required into passing when they just entered the university. However, six months into studying the course, 31% of the students surveyed in survey 2 agreed that their only expectation of the course was just to pass it. The number of students possessing such a passive attitude toward their learning outcome was tripled since the time the students arrived.

The reason for this deterioration in learning attitudes during the learning process may be partly due to the perception of the teaching style, which is discussed in section 4.2.3. The course, which is perceived as irrelevant and dull, may have caused this decline in learning motivation. This finding supported the thesis of this research: the learners' affective responses and their perceived goals of the course are crucial to their learning motivations and strategies.

(3) Study hours

The third indicator to illustrate the students' learning attitudes is their study hours out of class. The results of the students' original expectations and further evaluation of actual implementation are presented in Figure 4.14.

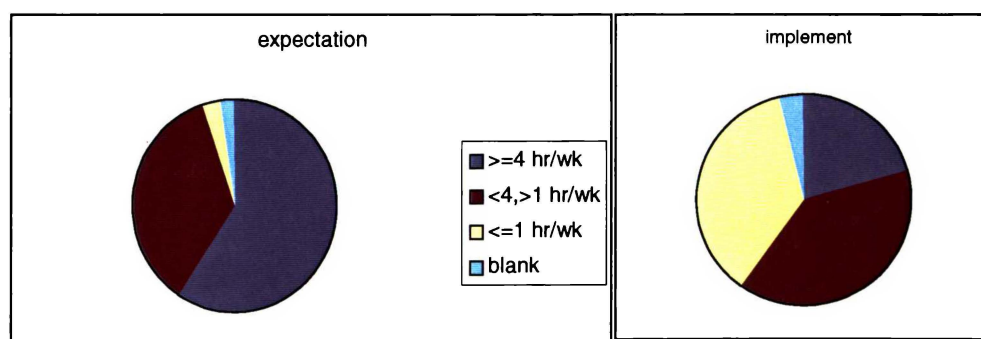


Figure 4.14 A comparison between the students' expectations and implementation of study hours out of class

In phase 3 of this research the students' study hours in physics out of class were investigated. Over half (59%) of the incoming students in survey 3A answered that they expected to study over 4 hours a week for this course. However, by the fourth week, as found in survey 3B, only about 21% of the students fulfilled this aim. At the low end of the scale, 97% of the students initially planned to study at least longer than one hour a week out of class for physics, but unfortunately, 37%

of them failed to reach even this low standard.

Regardless of their academic background and intellectual ability, with such a limited learning commitment, this group of students was unlikely to attain satisfactory academic performance. The percentage of the students who studied no more than 1hr/wk (37%) was even slightly higher than the failed percentage, which was about 30%. This implies that the lecturers have given grades generously, and the actual learning outcome may be even worse than the students' grades imply it to be.

(4) Memorising formulas without understanding

The last statement regarding learning attitudes is the students' adoption of a superficial learning strategy: memorising formulas without understanding the concepts. In survey 1F, 87% of the incoming students expected to avoid memorizing formulas without understanding the concepts behind them, and only 2% of the students expected to adopt the superficial learning approach. However, by the time of survey 2, when students had studied three quarters of the course, their initial expectations had drastically reduced. Almost opposite to what was expected, only 9% of the students denied that they memorized the formulas without understanding the concepts behind them, and 79% of the students admitted that they had adopted a rote learning approach.

The reasons for such a high proportion of students adopting rote learning rather than a comprehension approach may include both the assessment design and the learners' commitment.

As discussed in section 4.2.3, the design of the unified examinations may tend to assess recall of facts. Owing to the assessment design, rote learning may be perceived by the students as being more efficient than seeking comprehension of the concepts, and therefore encourage the superficial learning strategies. This is indicated by the fact that the rote learning problem was prevalent among all classes and independent of different teaching styles (see section 4.2.3). Meanwhile, the prevalent low study hours reported by the students may be a result of the insufficient learning commitment. Since many students were found to spend an unreasonably short time studying physics out of class, they may be forced to

cram most of the content within a very limited time before sitting the examinations.

To summarize, the students' actual learning attitudes and adopted learning approaches were found to seriously mismatch their original expectations. The learning experiences seemed to not simply fail to promote the students' learning motivations, but rather, to drastically deteriorate learning motivation and strategies.

The findings of the deterioration of learning attitudes were in accordance with the findings of the students' negative comments about the course design (see sections 4.2 and 4.3). The teaching design, which appeared to (1) fail to address the goals of the course (irrelevant), (2) neglect learning interest (boring), (3) be unaware of learning pace (too fast), and (4) provide little time for participating in the learning process (no interaction), may all have an influence on the deterioration of learning attitudes.

The significant deterioration of the students' learning attitudes found in this research provided a sign of warning about traditional teaching, which focuses on teaching and seriously ignores the students' learning.

The next section discusses what the students perceived as being the major barriers to successful learning outcomes.

4.5.3 Learning barriers

With respect to the poor academic achievements, the students' opinions about their main learning barriers were investigated in surveys 1F and 1S. Details about the questionnaire design are explained in section 3.3.2.

Survey 1F was designed to investigate the first year students' opinions about their learning barriers in high school physics, and survey 1S was about the second year students' perceptions of the barriers in university physics study. The results are discussed below.

- ***Results overall***

Both groups of students shared similar opinions about the learning obstacles in

general. The results are listed in Table 4.10.

Table 4.10 Learning barriers in physics perceived by the first and second year students

Learning barriers		2 nd year	1 st year
Learning habit	Study method	54	69
	Study time	55	65
Curriculum design	out of class resources	35	63
	dull content	34	47
Teaching approach	teaching methods	21	38
Learners' background	English	40	
	mathematics	24	24
	physics concepts		23

According to the data shown above, the learning barriers as perceived by the students appear to be in the order of the four main categories. Learning habit was regarded as the first major cause of unsatisfactory learning outcomes. Curriculum design was the second factor, which received more concern than the teaching approach. Learners' academic background appeared to be the least important factor to result in poor learning achievement. More details are discussed below.

- ***Learning habit***

Learning habits, including insufficient study time and inappropriate study methods, are the two most important reasons that students felt that they could not perform well in learning physics. The agreement percentages of both these two items were over 60% for the first year students and over 50% for the second year students. This may be a good sign that the learners were aware of their own problems and responsibilities rather than blaming their poor results on external factors, such as the course design or teaching skills. Since the main problem is perceived to be their own learning strategies, which can be controlled by themselves, the students can have stronger confidence about improving their

learning outcomes in the future (Abouserie, 1995; Dweck, 1975; Feather, 1982).

However, in this research, it was also found that learning attitude is not independent of teaching. Rather, learning attitude and learning strategy are very closely related to the students' perception of the course (section 4.2.3), and the perception of the course is closely linked to teaching style (section 4.2.2). Therefore, teaching style may be crucial to learning attitude, which includes learning habits and learning approach as discussed in this chapter. A study by Kember, Jamieson, Pomfret and Wong (1995) showed that workload and assessment have a close relationship with study time and study strategies. Therefore, the students as well as the lecturers both need to make an effort to overcome this major barrier to learning.

- ***Teaching content and methods***

Both groups of students expressed stronger concern about teaching content than about teaching methods. About half of the first year students and one third of the second year students agreed that the teaching content was boring and therefore retarded their learning. Only about one tenth of the number of the students who felt that the teaching content contributed to retarding their learning agreed that the teaching method contributed to retarding their learning. The students seemed to emphasize the teaching content design more than the teaching approach. The students' focus on teaching content rather than teaching approach may be an indicator of their commitment to the traditional transmitted way of viewing learning.

The problems with the existing content design are discussed in sections 4.1.4 and 4.3.1, including problems such as covering too much, being impractical, and being out of date. The problem of the teaching method, namely that there was a lack of interaction between the lecturer and the students, is discussed in section 4.3.1. In the intervention teaching, the researcher designed a new program modifying the teaching content design, as well as introducing more interactions while teaching, and the results will be discussed in chapters 8 and 9.

- ***Academic background***

The required academic background for learning physics includes: mathematical

skill, physics concepts and English reading. The students regarded reading English version textbooks as much more challenging than the required mathematical skills, therefore making learning physics difficult. Forty percent of the students replied that weakness in English reading became a barrier to learning physics. Many physics lecturers may ignore this unexpected problem when teaching. This difficulty in reading English for Taiwanese students is consistent with the findings of the study by Kember, Ng, Tse, and Pomfret (1996) in Hong Kong.

Fewer than one quarter of the students agreed that the difficulty of mathematical skills and physics concepts was the main reason for their poor achievements in learning physics. Based on the students' responses, these two factors were perceived to be the two least significant factors hindering students learning physics, and were less important than the problems of learning attitudes, teaching content design, and teaching approach. The students' opinions may remind us that when dealing with the unsatisfactory academic performance of the learners we have to possess a wider scope to allow us to link to the learners, rather than focus on the difficulty of the subject itself.

The trivial status the students attributed to the difficulties caused by their physics and mathematics background was very different from many studies in physics education in western countries, which often regarded the students' weak background in physics as a prevalent and major problem in learning university physics (Dickie and Farrell, 1991; Hart and Cottle, 1993; Rowell, Dawson and Pollard, 1993; Redish, 1996). This difference implies that the high school physics background of the incoming Taiwanese students may be stronger than that of the western countries, and this was in fact shown in that test as will be discussed below.

The findings of the crucial role of the students' learning habits in retarding their academic performance in physics when compared with the challenge of the subject itself highlighted the status of the students' motivational considerations in determining their learning performance. This finding supports the key notions of this thesis: In addition to the cognition consideration, physics lecturers should be more concerned about and should put more effort into developing the students'

learning motivational beliefs.

The next section makes a comparison between Taiwanese and American students' academic background.

4.5.4 Academic background in physics

In this section, the students' academic background in physics is discussed. An understanding of the students' background in Taiwan compared with that of the American students' can provide some information for the Taiwanese lecturers to help them with their teaching strategies.

As in many other countries, most of the university physics courses in Taiwan have adopted a textbook from the United States. However, the Taiwanese high school graduates' background in physics may be different from that of the American students, and therefore the usage of the textbook may become problematic to university physics education in Taiwan.

In order to have an idea of the physics background of Taiwanese and American students, two steps were adopted: (1) a comparison of Feng-chia students and American students, and (2) a comparison of Feng-chia students and other Taiwanese students.

(1) Feng-chia students versus American students

The researcher translated the English version questions of the Force Concept Inventory (FCI) (Hestenes, Wells and Swackhamer, 1992) into Mandarin to assess the background of the Taiwanese students, in order to compare the backgrounds of the students in the two countries. The test was given during the first lesson when the students entered Feng-chia University. The results of the students at Feng-chia and in the US are listed in Table 4.11.

Table 4.11 A comparison of Taiwanese and US students' performance in the FCI

Groups of students		Average score
The Feng-chia students	Environment Science (107) ³	60
	Aero engineering (54)	66
American students	32 Universities (4832)	40-50
	Harvard university	72

According to Hake's (1998) research, most of the incoming university students in the United States obtained an Force Concept Inventory score mainly ranging from 40 to 50. His study consisted of 4832 university students. In Taiwan, the researcher tested two groups of students with different academic backgrounds, consisting of 161 students. Regardless of the slight difference between the two levels of the Taiwanese students, the average performance of the Taiwanese students (60-67) was much better than that of the American students in Hake's study. The only institute that appeared to be slightly stronger in the area of the students' background was Harvard University.

The next question was to find how the students participating in this research are located amongst all Taiwanese students. The results of their performance in the entrance examinations may provide some clues.

(2) Feng-chia students versus Taiwanese students on average

The physics background of the Feng-chia students when compared with the Taiwanese students on average is listed in Table 4.12.

³ The number in the bracket indicates the number of students who sat the test.

Table 4.12 A comparison of the high school physics background of the Feng-chia University students and all Taiwanese students

Groups of students		Performance in the entrance examination	
		Average score	Percentage of all candidates
Subjects joining this research	Environmental Science	34	44% ⁴
	Aero Engineering	49	63%

The results show that the Aero engineering students were about 63% amongst all candidates and had a stronger physics background than the Environmental Science students. The Environmental Science students background was slightly lower than the average nationwide as they were located at 44%. Therefore, the background of the students participating in this research is about average (50%) when compared with all high school graduates in Taiwan. In summarizing the results of Tables 4.11 and 4.12, the Taiwanese students' background in physics appears to be significantly better than that of the American students on average.

One reason for the Taiwanese students performing better than the American students may be because the teaching hours in Taiwan are more than that in the US. From survey 3A, the first year students reported that they spent an average of 14 teaching units in high school physics in their three years of study. One unit indicates 1 hr/wk · yr.

This finding may explain why the Taiwanese students experienced less difficulty as a result of their physics background when learning university physics, than the western students did (see section 4.5.3). The comparison may also confirm that the major barriers of the Taiwanese students in learning university physics were in affective aspect rather than cognitive aspect.

This result also implies that the teaching strategy needs to be modified to match

⁴ The percentages indicate the level of the students compared with all candidates.

the physics background of Taiwanese students when adopting a textbook from the US. Since the students have already spent a great deal of time studying high school physics, they might feel that it is repetitive or even boring if the university physics lecturers teach totally according to the textbook. The textbook is mainly designed for the American students' background. Detailed suggestions for modifying the teaching strategies will be discussed as part of the intervention program design in chapter 7.

4.5.5 Summary

There are four points to summarize the learners' perceptions of their learning:

- (1) Most of the incoming university physics students held a positive attitude towards university study. They expressed their willingness to adopt deep-level learning strategies, and to put much effort into learning, and they also expressed their expectations of becoming informed, and being independent learners.
- (2) However, their original high self-expectations were unable to be achieved, and the teaching process seemed to deteriorate rather than promote their learning attitudes.
- (3) The students perceived the learning barriers as mainly their own problems; they felt that insufficient study time and inappropriate study methods were the major reasons for their poor performance in university physics.
- (4) Physics background in high school was regarded as a minor factor amongst all possible learning barriers. The Taiwanese students' high school physics background appeared to be much stronger than that of the American students on average.

This Chapter has discussed the students' opinions about learning university physics: the course design, the teaching, and the learning. The next chapter (Chapter 5) discusses the physics lecturers' views about teaching the course. The responses of these two groups will be compared and summarized in Chapter 6.

Chapter 5

Lecturers' points of view about teaching and learning

5.1 Introduction

In this chapter, the physics lecturers' points of view about the university physics course are discussed. In addition to the researcher, there were ten physics lecturers at Feng-chia University. Opinions discussed in this chapter are based on two research activities: lecturer interviews and a lecturer survey.

Eight physics lecturers participated in the interview, and four main topics were investigated: (1) the course design, (2) the classroom climate, (3) the lecturers and teaching approach, (4) the learners and learning.

The domain of each topic overlaps. Therefore, some questions may include more than one topic and will be discussed in the section of the major topic.

After the lecturer interviews, the researcher designed a questionnaire for the lecturers, and seven physics lecturers completed the open-ended questionnaires in phase 3.

Details of the research design for investigating the lecturers' points of view are presented in section 3.3.3.

In this chapter, the lecturers' responses to both the survey and the interviews were combined and are discussed under six headings:

- (1) the course design,
- (2) the physics classroom,

- (3) the teaching approach,
- (4) lecturers' responses to improving the learning outcomes,
- (5) influence of education research on lecturers' teaching, and
- (6) summary of the lecturers' points of view.

The following discussion is in accordance with these six points in sequence.

5.2 The course design

With respect to the course design, several issues emerged in the lecturer interviews and some of them were re-explored again in the lecturer survey. Their opinions are discussed in four headings as follows:

- (1) the unified policy,
- (2) the aims of the university physics course,
- (3) criteria of content selection: interview responses, and
- (4) content selection: lecturer survey.

5.2.1 The unified policy

- ***The unified syllabus and examinations***

The Physics Center of Feng-chia University has implemented a unified system for both syllabus and examination for the last 15 years. Details of the unified policy are presented in section 1.1.

- ***Lecturers' responses to the unified system***

When lecturers' opinions about the unified system were investigated, it was found that the eight lecturers' attitudes were clearly dichotomous, since they either agreed or disagreed, with the policy, without any neutral responses. Six out of the

eight lecturers held opinions opposing the unified system policy and only two agreed with the current arrangement.

The reasons for supporting the unified system were mainly based concerns of “fairness” to the students’ grades and “the standard” of the lecturers’ teaching. For example,

The [unified examination] policy can prevent some student complaints about discrepancies in assessment standards among different lecturers... Fairness is especially important to Chinese students... Particularly, we have such a big enrollment each year. If we cancelled the unified system, I am afraid that many students will create ‘noise’ about assessment standards and bring us much trouble. (L1)

I believed that all lecturers in our center were highly committed; we do not need the policy to keep our teaching progress. But I knew some part-time physics lecturers, perhaps they don’t regard this as their major work, their teaching progresses were far behind our syllabus. It is still necessary to control these lecturers’ teaching through the unified policy. (L5)

On the other hand, six out of the eight lecturers disagreed with the unified policy. They expressed much criticism of the system. Their main arguments included:

(1) Five of the eight lecturers commented that the unified syllabus has forced their teaching pace unreasonably fast. For example,

To cover the syllabus, I have to keep dumping information on the students. I have no time to wait while they absorb the teaching content. Looking at their facial expressions, I know that they have not understood yet, but I still have to keep carrying on... Yes, we finally cover the entire assigned syllabus, but how much do our students absorb from our teaching? (L7)

I don’t agree with the existing unified policy because the assigned syllabus is too heavy. It gives us much pressure to cover it (within the time constraint). There is no time for us to supply something we think is worthwhile to introduce to our students. I suppose that the unified syllabus should be adjusted from maximum requirement coverage to minimum requirement coverage. (L4)

(2) Four noted that flexibility is essential for lecturers to their teaching design. For example,

(In the syllabus meeting) I don’t want in waste my energy arguing (with our colleagues) about what (content) should be put in and what should be left out. It is not the problem of right or wrong. Every lecturer has their own reason (and consideration) to put something in or out. Why not just let each

lecturer have his/her own choice?... Some lecturers emphasize fairness (when they support the unified policy), but our students are so different, like electronic engineering and mathematics students. Their backgrounds are so different, how can we use the same standard to assess them? (L3)

- (3) Three stated that without the unified policy, lecturers could have more authority to take more control of their students' learning. For example,

I believe that once the unified examination is cancelled, our students will care more about what we emphasise in class. Since we almost have no control of the examination questions, students will not concentrate on what we teach in class. Attending class for them seems to be only for roll calling... It is really sad that as a lecturer, I still have no control of our teaching. (L6)

- (4) Three stated that without the unified policy, lecturers could take more responsibility for their own teaching. For example,

I believe that all lecturers in our center are committed, and do not need to be controlled by the unified syllabus. (L2, L3¹) The unified system gives us an excuse to fail in our teaching. Since none of us have any flexibility in our own teaching, we do not need to take responsibility as lecturers. (L2)

- (5) Four lecturers concluded that the policy has become a barrier to achieve their teaching aims. For example,

The unified policy has become the main obstacle to reaching my teaching aims... Many good topics, I can only teach them in the summer course. (L3)

I wonder how the (unified) policy can have existed for so many years... The fairness (to students) is fake, the coverage (in teaching) is ridiculous. I can see only the disadvantages of this policy. Cancel it, I believe that every lecturer will perform much better than now. (L6)

This unified policy was not a compulsory system of the Feng-chia University but was initiated by an ex-director of the physics center. Therefore, the policy could be cancelled by consensus amongst the lecturers in the physics center. Although most lecturers expressed their objection to the existing unified policy in the interviews, most of these lecturers have behaved as a silent majority in the meetings for more than 10 years, and the system had firmly existed in the Physics

¹ L3 used almost precisely the same words.

Center. The silence could be due to the learners' indifference regarding their teaching outcomes, and could also be yielding to the authority of the minority lecturers who agreed with the policy.

Meanwhile, from both sides of the responses, many lecturers seemed to regard content coverage as an indicator of teaching commitment as well as equate teaching design as content selection. Other issues such as the aims of this course, alternative teaching approach, and assessment orientation, were not raised regarding the restrictions of the unified system by the lecturers while interviewed. This result indicated the physics lecturers' transmitted way of viewing teaching and learning, and thus they focus more on teaching content rather than other issues.

5.2.2 The aims of the university physics course

The second issue of the course design was the aims of the course. All physics lecturers agreed that the University Physics Course is important to the Science, Mathematics, and Engineering (SME) students. The aims of this course can be divided into two aspects:

Five out of the eight lecturers stated the importance of being equipped with general physics knowledge of the students learning university physics. For example,

This (course) is the last chance for the engineering students to learn physics. At least we need to let our students be equipped with the knowledge basis to understand what physicists talk about. University students should realize the importance of possessing knowledge in all relevant areas, not just focussing on their majors. (L8)

I know what the students want. They only want to learn something directly linked to their major. Like my mechanical engineering students, they studied much harder in the first semester (mechanics and thermodynamics) than in the second semester (electromagnetism). But I would never agree with this kind of narrow perception of what we should expect our students to learn. This is the last chance for them to know about physics. An overall understanding (in physics) is what we need to insist upon. (L3)

Six lecturers noted that university physics can enhance students' thinking ability. For example,

Learning physics can cultivate a thorough thinking habit...Many problem-solving questions require a thoroughly logical derivation. This is why some physics graduates can even have outstanding achievement on Wall Street (stock market). (L7)

Some of my university classmates shifted their major (from physics) to engineering, and they all had outstanding achievements in their study. This is because when they studied in physics they were trained in strong logical reasoning ability. I think logical reasoning ability is important to these engineering students in their future. Solving physics problems can cultivate this kind of thinking ability. But most of our students do not know about this importance of the thinking ability. (L2)

The physics lecturers seemed to possess a wider perspective of the aims of this course than their students. According to the lecturers' opinions, a wider range of physics knowledge and developing thinking ability are beneficial to long-term development rather than simply to advanced study. Compared with the lecturers, the students' reasons for taking the course were mainly based on practical points of view, i.e., providing a knowledge basis for majoring study and for applications in everyday life (see section 4.1.1).

Without being advised of their students' opinions, four lecturers actively criticized the narrow perspectives of some students and engineering lecturers who tend to focus on the technical subjects and pay too little attention to the basic science courses. For example,

The course design of some departments has become narrower and narrower, focusing on their majors, and the university is more likely to become a vocational training center. (L6)

Summarizing the lecturers' opinions, most of the physics lecturers seemed to achieve a consensus about the aims of the university physics course. Although the lecturers appeared to possess a wider scope of viewing the aims of the course than the students, the lecturers' perceptions seemed to be limited to the cognitive area, ie, knowledge acquisition and intellectual development. Other perspectives, such as influencing the students' affective responses to the course, as well as developing students' perceptions regarding learning in university physics or even throughout their entire university education (Ramsden and Martin, 1996; Hammer, 1995b), were completely ignored by the lecturers. Although the lecturers saw the problems of the students' narrow perspectives as one barrier to

learning university physics, they seemed not to expect themselves to overcome this barrier when teaching the course. Issues outside of the cognitive area, such as affective responses and beliefs/perceptions, may be too abstract or trivial for the physics lecturers with respect to the aims of this course.

The lecturers limited their focus on cognitive considerations regarding teaching design, and particularly, they focused their concern on teaching content design. The next issue is to search for a better insight into the lecturers' view of content design.

5.2.3 Criteria of content selection: Interview responses

The third issue of the course design was content selection. Criteria of content selection may be closely linked to the aims of the course. In the interviews, physics lecturers' responses to teaching content selection were discrepant; their opinions discussed into four points below.

- *Coverage of content vs. reasonable pace*

The first issue in content selection is content coverage versus reasonable pace. In lecturer interviews, all of the eight physics lecturers agreed that the content of the textbook is too massive to cover within the one-year course. However, the lecturers' attitudes toward this problem are not consistent. Two opposing opinions were found. Six lecturers agreed that reasonable pace is more important, while two regarded content coverage as the lecturers' responsibility.

Six out of the eight lecturers noted that reasonable teaching pace is more important than content coverage. They complained that the load of the assigned syllabus was too heavy. They claimed that in order to cover the unified syllabus, the teaching pace has become unreasonably fast, and so they suggested to drastically reduce the selected content. This argument is based on the difficulty of students' learning caused by the fast teaching pace. For example,

Recently I often think of a quote from (the journal of) Physical Review: 'learning university physics is just like drinking water from the hydrant'. We have supplied too much and too fast, and hence students can only absorb very little from it. The syllabus is too heavy for our students. (L8)

Of course, the syllabus will never be too heavy for us (lecturers), but it is definitely too much for the students....The key point should be how much they have learnt, not how much we can cover. (L6)

Only if we can have 10 hr/wk of teaching time, can we think about covering all topics...With only 3hr/wk, we should ask which topics are more valuable to students and not be concerned about what topics we have omitted. (L3)

On the opposing side, two lecturers were concerned more about content coverage. They both claimed that covering the content is their duty as physics lecturers. For example,

To try our best to cover most topics is our responsibility as physics lecturers, since the title of this course is called General Physics ...It (the title) has already been announced, so we have to fulfill our duty...If do not teach, it is our fault.(L1)

The syllabuses have already been reduced a great deal in recent years... Although some students still complain about my teaching pace (that it is too fast), I think there is not much space for us to cut even further. If we omit more content, the course may become simply mechanics, or simply electromagnetism, or even nothing at all. It cannot be called a physics course. (L5)

In summary, most of the lecturers regarded equipping their students with general physics knowledge as an important aim of the course, while they also emphasized that teaching content should be drastically reduced in order to fit the students' learning pace. However, general physics knowledge may indicate a certain amount of coverage of the teaching content, which could be greater than what the students expected. As found in students' survey, many students disagreed with the current amount of content coverage (see section 4.1.2) and the fact that the teaching pace was too fast was the students' first concern (see section 4.2.1). The significant disagreement between the students and the lecturers regarding content coverage may not only be due to the students' learning ability, but also be due to the discrepancy between the two groups' perceptions of the aims of the course (Ames, 1992; Donald, 1993). The students might have complained about the coverage and teaching pace partly because they could hardly see any reason for learning the material.

- ***Mathematics versus phenomena in everyday life***

The second issue of content selection was mathematics versus phenomena in everyday life. When discussing the course aims with the physics lecturers, some lecturers claimed that problem-solving is beneficial to cultivate the students' thinking ability, and thinking ability is one important aim of the university physics course. The lecturers' responses to this issue can be grouped into three categories:

- (1) Three of the eight lecturers noted that solving problems is their major teaching task. For example,

Physics is to use calculus to solve problems... We cannot always ask for examples linked to life in every topic, [because] physics is [to deal with] theory rather than to develop practical applications. This is the character of physics... This is the difference between pure science and applied science. Applied science focuses more on linking to life. (L1)

[During the teaching time], I work very hard in solving the problems step by step on the blackboard to ensure that my students have no difficulty in following the procedure when revising their notes after the class. Mathematical ability will be beneficial to their advanced courses. (L5)

I think problem solving is important. Enhancing mathematical skill is an important task for the first year students, because they will need it in the coming years of studying advanced courses. (L8)

The above opinions may be a reflection of the existing teaching design, where lecturers spend a majority of their teaching time on the mathematical derivations of both physics theories and problem solving.

- (2) Two lecturers disagreed the existing teaching design, and suggested to reduce the calculation and increase physics concepts. They noted that more application examples to link physics and everyday life experiences should be introduced in physics classes in order to promote learning interest. For example,

Complicated mathematical derivation is useless to them; it can only reduce their learning motivation... Recently, I put much effort into searching for teaching resources, e.g. application examples, interesting stories of physicists. I have introduced this material into my classes and received much feedback from my students. (L4)

In every physics class, we should start from life examples to refresh our students. (L6)

The physics lecturers' considerations of introducing everyday life phenomena are mainly based on promoting learning motivation.

(3) Two lecturers held a neutral attitude toward this issue. They noted that both problem-solving and life examples are important. For example,

Physics phenomena and examples in everyday life are always attractive to students, but mathematical calculation makes them feel bored... We need to search for more examples to link to their life to make this course interesting....(However), some students may feel we lower the standard of this course if we reduce the mathematics and add more application instead. (L2)

Yes, we need to provide many life examples to maintain our students' learning interest. But we also need to maintain the quality of this course, because our students will need to compete with others after graduation... I don't think we can reduce the portion of our teaching time in problem-solving any further. (L7)

Based on all of the lecturers' opinions, they seemed not to link the cognitive essentiality of providing familiar contexts to students with learning physics concepts. According to the constructivist view of learning, concepts are contextualised. Context determines the meanings of words as well as the appropriation of the concepts (Bell B., 1993; Hipkins and Arcus, 1997; Hennessy, 1993; Linder, 1993). The physics lecturers seemed to isolate physics concepts from phenomena. Therefore, life phenomenon is regarded as auxiliary when teaching physics for making classes more appealing.

Also, the lecturers imply that problem-solving and mathematics are indicators of the quality of the course. Therefore, they are faced with the dilemma of choosing between maintaining learning interest and the quality of the course. The lecturers' opinions about the issue of interest versus quality were investigated further in the lecturer survey in phase 3, and will be discussed in section 5.5.3.

The students may have very different perceptions of problem-solving and life phenomena. In the intervention student interviews (sections 9.1.1 and 9.1.2), problem-solving seemed to be perceived as being of no help to stimulating

thinking, and life examples were perceived to have their own value in practical applications as well as helping learners to understand the physics concepts.

- *Consideration of students' majors*

The third issue is whether the students' majors should become a consideration in content selection. In the interviews, all lecturers agreed that while selecting the teaching topics, students' majors should be taken into consideration, but should not be the only factor to decide the content. For example,

Students' majors should be part of our consideration, but we cannot just limit to their major area when selecting the teaching content. This is the last chance for them to learn physics. I will also think about what topics are valuable for them to understand the world of physics. (L3)

If we give the examples linked to their majors, students will be glad to come to the class. This is helpful to promote their learning motivation. But I think the perspectives of many engineering students too narrow. They don't want to learn anything, which appears to be irrelevant to their majors. (L8)

- *Classical versus modern physics*

The fourth issue in content selection is classical physics versus modern physics. In the current university physics class, teachers usually run out of time before reaching the modern topics, e.g., Relativity and Quantum Mechanics.

At Feng-chia University, modern physics topics has been almost neglected in the unified syllabus as a result of the massive content in classical physics. It is very likely that introducing modern physics will lead to reducing classical topics. What then were lecturers' opinions about introducing modern physics and reducing some classical topics?

The interviews revealed that three lecturers disagreed and two agreed with adopting some more modern topics.

Those who disagreed with introducing more modern physics regarded classical topics as an essential basis for learning modern physics as well as arguing against the value of introducing modern physics topics to the students. For example,

We don't even have time to finish the classical topics, so it is impossible to introduce modern physics... To the first year students, modern physics is only dealing with some facts like teaching history. (L1)

Without a firm basis in classical physics, students find it difficult to learn modern physics. (L5)

On the other hand, the opposing group of lecturers have different perceptions towards classical and modern physics topics:

I have tried to teach Quantum Mechanics and Relativity in the summer course, and students felt refreshed about the content... It is wonderful to show them 'different ways of thinking' in modern physics which is challenging to the traditional thinking format... Some students actively came to discuss with me the phenomena of Relativity after class; they are highly engaged. (L3)

I would like to reduce some classical topics and introduce some modern physics if I had the flexibility to design my own content. Students have the capability to learn classical physics by themselves. (L8)

From the above statements, the same teaching topic may mean very different things to different lecturers. For example, some lecturers perceived modern topics, as just dealing with the facts of science history, while others emphasised that modern physics topics were to guide the students different ways of thinking. Different perceptions about physics topics determine the value of the topic and influence the lecturers' decision in content selection. Therefore, it is not surprising to see diverse opinions among lecturers in most of the criteria about the course content. Different lecturers' perceptions of each topic can also result in different emphasis and ways of interpreting the materials. Therefore, although all the lecturers were forced to cover the same topic yielding to the unified system, the students in different classes had vastly different perceptions of the curriculum (section 4.2.2).

The lecturers might have disagreed with the introduction of modern physics because they were committed to a positivist rather than to a constructivist view of the development of science physics. The constructivist view highlights the role of the paradigm in determining the criteria of the development of science knowledge, and the incommensurability of the knowledge in different paradigms (Kuhn, 1970). Many of the contemporary physics concepts, which lie in the fields

of quantum physics and relativity, are exceedingly abstract when compassed with the thinking format of classical physics (Linder, 1993). According to this notion, teaching modern physics should not aim to pile extra information up out of the classical concepts, neither just to tell the history as noted by the opposing group, but rather, it is to guide students towards adopting a different way of thinking, as the other group claimed.

Comparing the lecturers' responses to the content selection with their students' expectations (in section 4.1.1) and perceptions (section 4.2.3) of the course, two kinds of mismatch were found:

- (1) Lecturers' opinions were inconsistent with those of the students. There were mismatches on the points of: (a) raising the status of students' majors in selecting content and (b) introducing more life examples and reducing problem-solving.
- (2) Agreement of opinion between the students and the lecturers may not always lead to agreement of action. This kind of mismatch was significant in the criterion of content coverage versus reasonable pace. Although most of the lecturers agreed, in the interviews, that reasonable teaching pace is more important than content coverage, most of the students still felt that the teaching pace was too fast.

The researcher anticipated that this research could achieve a better understanding by the lecturers of what their students expect and perceive. Therefore, she provided the findings of the students' opinions to the lecturers, and hoping to promote the lecturers' awareness of the mismatch in the area of content selection.

5.2.4 Content selection: Lecturer survey

The same issue about content selection was investigated further five months after the lecturer interviews. The purposes of the further investigation of the same issue were

- (1) to investigate whether lecturers' opinions altered as a result of knowing their

students' responses (results of survey 2),

- (2) to have more systematic and quantitative results to show the distribution of each opposing end (agree and disagree) of criteria of content selection.

The lecturers were asked to select what they thought needed to be emphasized and what could be omitted because of time constraints. The lecturers were able to select items given by the researcher or to express some ideas that did not appear on the lists. The selected items along with the results from the lecturers are listed in Table 5.1.

Table 5.1 Lecturers' responses to content selections

Selecting items	should be emphasized	could be omitted
1. cover the content in the textbook	1	5
2. summarize the key point in each lesson	4	1
3. synthesize the concepts in several chapters	2	3
4. derive and verify each theorem	2	1
5. introduce examples to elucidate the physics concepts	7	0
6. link the theory and application in everyday life	5	0
7. solve the problems and teach the problem solving skill	1	3
8. provide the knowledge base for advanced courses	3	1
9. provide reference information beyond the textbook	1	1
10. others	0	0

The results are discussed in two steps: (a) the overall results, (b) a comparison of the lecturers' opinions with those of the students' expectations, the researcher and the students' perceptions of the existing teaching.

From the results shown above, the responses of content selection were fairly consistent amongst all physics lecturers. Most of them regarded that while teaching university physics, lecturers should place emphasis on introducing examples to elucidate concepts, linking the theory and application to everyday

life, and summarising the key points in each lesson. Also, due to the time constraint more of the physics lecturers agreed that the teaching goals which could be omitted were coverage of the textbook, solving the problems, synthesising the concepts in several chapters.

The survey results are discussed in more detail as follows:

The first issue was the teaching task of summarising key points and synthesising concepts. The lecturers seemed to see the need for summarising the key points in each lesson more than synthesising the concepts amongst chapters. This preference implied that the current teaching may mainly focus on clarifying each individual concept, rather than on integrating them as a whole. This type of teaching may fail to guide students towards adopting a deep level learning strategy. Many studies in physics education have revealed that novice learners tend to search for "hot formulae" and plug into the problems without imagining the phenomena and clarifying the physics concepts. As a result, the adopted formulae are often incorrectly applied (Gautreau and Novemsky, 1997; Linder and Hillhouse, 1996; Zajchowski and Martin, 1993). To avoid encouragement of superficial learning, the summary should guide students towards integrating concepts and principles in order to develop a coherent understanding instead of only highlighting the "hot formulae".

On the other hand, synthesis is categorized as high level learning (Cannon, 1988). When a new concept is presented to the learners, they need to make sense of it as well as link the new with the existing concepts (Freyberg and Osborne, 1985; Posner, Strike, Hewson, and Gertzog, 1982). Therefore, synthesising concepts among chapters should be an essential task for learners to develop a better understanding of the physics concepts (French, 1988; Prentis, 1996; Ridgen, Holcomb and Di Stefano, 1993). According to the lecturers' responses, this task may be seriously absent in physics class due to the lecturers' perceptions. The lecturers' preference also indicated that they have over-simplified the process of teaching and learning physics compared with physics education researchers.

The second issue was coverage of the textbook. Five out of the seven lecturers

agreed that the teaching of physics should not be devoted to covering the content of the textbook. According to the lecturers' responses, enhancing the understanding of physics concepts is regarded as more important than content coverage. Compared with the opinions of the lecturer interviews five months prior to the lecturer survey, the teaching focus has shifted from coverage to understanding. This new consensus amongst the lecturers about reducing the coverage of the textbook also agreed with the students' expectations (see section 4.1.2). This research process might have facilitated the alteration in lecturers' opinions regarding content coverage, through the lecturers' interview and transferring the students' opinions to the lecturers.

The third issue was the importance of life examples versus problem-solving. All of the seven lecturers agreed that teaching physics should provide sufficient examples from everyday life. All of the seven lecturers explained that life examples were to help students elucidate physics concepts, and six out of the seven noted life example help indicate the relevance of the course to their life. Also, three physics lecturers agreed with reducing the proportion of teaching time spent on solving problems. Lecturers' evaluation of the importance of life examples and skills of solving problems is consistent with students' opinions (see section 4.1.4).

Comparing the findings in phase 2 (lecturer interview) and phase 3 (lecturer survey), a shift of lecturers' opinions towards the students' expectations was found, and this shift in the lecturers' thinking has led to an adjustment in implementing the existing teaching.

In summary, the above discussions of lecturers' opinions with respect to the course design have several implications. When compared with the literature, lecturers' perceptions about teaching and learning physics seemed much simpler than the arguments in the current literature. The lecturers tend to equate teaching content design to the whole issue of teaching design, which implies a transmitted view of teaching and learning. The lecturers were also found to limit the aims of this course to the cognitive aspect, and neglect the learners' motivational beliefs. At the same time some literature appeared to hold a positivist commitment to

viewing the development of physics knowledge. Finally, the lecturers' opinions with respect to content selection appeared to differ from the students, however a shift in the lecturers' opinions towards their students' preference was also found between phase 2 and phase 3.

The next section discusses the situations in the physics classrooms based on physics lecturers' perspectives.

5.3 The physics classroom

This section discusses the lecturers' perspectives regarding the situation in the classroom, including the students' involvement, the lecturers' support, and interactions between peers, and between students and lecturers.

The responses are discussed into four points:

- (1) the interactions in classroom,
- (2) reasons of lacking interactions in class,
- (3) ways to engage students in learning physics, and
- (4) summary of the classroom interactions.

5.3.1 The interactions in classroom

The first topic regarding the situations in their classroom was the interactions in the classroom. Five out of the eight lecturers acknowledged that their classes lacked interaction. For example,

They are always silent. The students are so indifference. Sometimes I even tried to make mistakes on purpose in front of them, hoping for someone to correct me. But most of the time, no one responded. (L7)

Four of them also noted that they felt very difficult to stimulate their students' engagement in class activities such as in-class discussion. For example,

Every time I ask them 'are there any questions', the response is always

silence. This makes me very depressed... I really don't know how much they have learnt or how they feel about the course. (L6)

This is probably a common problem in traditional university physics classes in many countries. Many articles noted the lack of interactions in physics classes (Holton and Horton, 1996; Meltzer and Manivannan, 1996).

In next section, the lecturers' opinions will be investigated to the reasons for the lack of interaction and the possible ways to engage students in the physics class.

5.3.2 Reasons of lacking interactions in class

According to the lecturer interviews, the classroom lacking students' responses can be attributed to both content design and learning attitudes.

- *The content design is overloaded and impractical*

Six lecturers claimed that the design of the teaching content was inappropriate to the students. They regarded the teaching content design as too heavy, too difficult and irrelevant. Therefore, the students lose their confidence and interest in learning physics. For example,

We force them to learn something too difficult and too fast (L4, L2); that is why students switch off in the [physics] class... The course is not useful either to everyday life or to their future, that is why they feel bored. (L2)

As physics lecturers, 'physics' means 'understanding the theory', but for our students 'physics' means 'foggy' initially and becomes 'let it alone'² eventually... They are mostly reluctant to learn physics... It is our responsibility; the first task is that we must do something to attract them back. (L4)

We make our students hate physics... There are times when I am aware that we may not take sufficient responsibility as lecturers. We do not care about their feelings, do not try to do anything to change our teaching, just let the problem (of lacking interaction) continue. (L6)

When the pace is too fast it is fatal for the learning interest. (L8)

² All the words in quotation marks in this sentence are homophones in Mandarin, pronounced "wu -li".

- ***Learning attitude: All they want is just to pass***

Three lecturers pointed out the problem of learning attitude, and one of them also agreed with the problem of content design mentioned above. They claimed that many students do not really want to learn anything but just want to pass the course and obtain the degree. For example,

In recent years, students have become mercenary. They enter the university just for the degree, but do not expect to really learn. (L5)

Sometimes, I intentionally include some errors and hope that my students can pick them up, but they disappoint me because no one has ever done it... They just want to pass the examination. (L7)

I have tried my best to inspire them (to engage in learning), but they just do not respond. (L2)

From the interviews, no one denied the importance of the students' participation in class activities. Five of the lecturers emphasised that they have put much effort into stimulating the students' involvement, but have failed. As a result, lecturers may gradually lose their confidence and willingness to try to encourage their students' engagement, and the classroom may remain a place for solo performance without interaction. One lecturer noted:

Since the students do not respond, no matter how much effort I put in, I think there is no point in trying to stimulate them... The effort I put into my teaching may not be satisfactory if I was at Harvard, but I think it is enough for our students... This kind of student only needs mediocre lectures. (L7)

5.3.3 Ways to engage students in learning physics

While many lecturers discussed the reasons for the lack of interaction between the students and the lecturers, possible solutions to draw students' involvement back to the physics classes were also investigated.

The lecturers suggested two ways to diminish the problem of the insufficient interactions in the physics classrooms, namely, course content redesign, and lecturers' attitudes to their students. These two ways are discussed respectively below.

The lecturers suggested about ways to make the course more attractive and comprehensible:

Firstly, four of the eight lecturers suggested to listen to the students' opinions before designing the course content. For example,

I think we need to respect our students' opinions, what they like and what they dislike. The students must feel interested in what we teach, then they will be willing to be involved in our teaching... But when we are designing our syllabus, we never think about what they want, but just talk about what we think is good for them. (L4)

Secondly, four noted the needs of reducing the course content in order to promote the students' interactions in class.

The time is so limited that I have to keep my focus on teaching and almost have no time to ask about the students' problems... If we want to increase the students' involvement, the first step is to reduce the assigned teaching content. (L6)

Thirdly, three of the seven lecturers noted the needs for reducing the amount of time given to teaching mathematics and introducing examples to link to everyday life. For example,

They (the students) do not respond because they feel bored...Examples in everyday life are always interesting to them and so can trigger their learning motivation. (L2)

Lecturers' opinions about improving the classroom interactions by adjusting teaching content design were consistent with their responses to the issue of content selection discussed in section 5.2.3.

In addition to the modifications of teaching content, three lecturers also pointed out the importance of lecturers attitudes, ie, showing high expectations of and deep concern for students, and the importance of being approachable in order to eliminate the students' hesitations and bridge the gap between lecturers and students. For example,

I think this (lacking of interactions) is because of the (students') confidence problems. Most students felt depressed about their Entrance Examination results for entering this university. They need encouragement to establish confidence at the beginning of their university study. (L2)

I usually give encouragement instead of criticism to my students... I show my genuine concern and interest about their new life at university... This is maybe why I can always establish a close relationship with my students... Students need to feel their lecturer is approachable, then they would dare to talk in class. (L4)

5.3.4 Summary of the classroom interactions

Summarising from the lecturers' opinions, several factors are required to promote the students' engagements in class. These factors include:

- (1) content design: Teaching content needs to be relevant to their experience, reasonable in pace, and suitable to the learners' level in order to promote learning interest and to refrain from undermining the learners' confidence.
- (2) lecturers' attitudes: Lecturers need to put effort into becoming approachable, establishing a friendly atmosphere in class, and actively trying to bridge the gap between lecturer and students.
- (3) learners' attitudes: The students need to see the value of the learning itself, not just for its rewards, such as grade or degree, and sincerely want to learn in the class. Then, the lecturers' efforts can be rewarded by the responses of their students.

In the lecturers' interviews, there were something missing regarding the "problem" of a lack of participation and interaction in physics classes. Firstly, in order to stimulate the involvement of the silent students, the lecturers limited their thinking solely to content design, and neglected consideration of alternative teaching approach design. They seemed to be more concerned with current content design than the traditional didactic teaching approach. Issues of alternative teaching approaches were totally ignored in regard to the students' participation in class activities. Secondly, while the absence of student participation seemed to be prevalent in all classes, lecturers' attitudes towards this problem seemed to be mild compared with their attitudes towards other issues, such as the unified policy. These attitudes imply that the lecturers did not regard the absence of responses from their students as a serious problem, and thus they may tolerate their students to behave as passive receptors. The lecturers' attitude

also indicates their transmission views of teaching and learning, and this attitude may reinforce the students' perceptions in the same way.

The issues of alternative teaching approaches was not raised until the researcher actively asked for their opinions, which is discussed in the next section.

5.4 The teaching approach

The third issue of the lecturers' views is teaching approach. Among the eight interviewees, most of them have long term experience in teaching the University Physics Course; five of them have been teaching this course for over ten years, and the other three have over four years teaching experience. For these experienced lecturers, what types of teaching approaches were perceived as beneficial and applicable to learning? What teaching approaches have they applied in practice in their classroom?

The lecturers' views of teaching approach were investigated in both the interviews and the survey, and four points are discussed with respect to this issue. The first three sections discuss the data from the lecturer interviews in the area of

- (1) unique-directional or interactive teaching approaches,
- (2) use of teaching-aids,
- (3) views of teaching tasks.

The last section presents

- (4) survey results regarding teaching approach .

5.4.1 Unique-directional or interactive teaching approaches

A number of studies of the university physics course have revealed the significant outcomes of an interactive teaching approach in comparison with the traditional unique-directional delivery (eg, Hake, 1997; Heller, Keith and Anderson, 1992). The features of the two types of teaching approaches are compared in section

2.4.1. This section discusses the lecturers' responses with respect to the two teaching approaches.

As noted above in section 5.3.4, the lecturers' responses concentrated more on teaching content selection than teaching approach. When asking them directly about opinions of applying an interactive way of teaching, they were more concerned about the existing barriers and disadvantages it may cause, than the potential advantages.

From the interviews, reasons which make lecturers reluctant to introduce an interactive teaching approach as a regular teaching method are discussed, with corresponding quotes, in five areas:

- (1) conservative learning attitude: Five out of the seven lecturers pointed out that students are more used to passively accepting than being actively involved due to their prior learning experiences. For example,

When I studied in the United States for my Masters degree, most of my lecturers applied in-class discussion. (In these classes), teaching often started from the students' questions and discussion of these questions took a majority of the teaching time. I guess lecturers in our university (Michigan University) could not survive if he/she only used traditional lecturing... (But) it is impossible to do the same thing (in-class discussion) with our students (in Taiwan). They have never had this kind training in secondary school. They don't know how to do it if we asked them to express their opinions. (L8)

Taiwanese students are not used to being actively involved in class. Just changing the teaching approach cannot help to solve the current problem, because I have tried it, and it failed. (L2)

- (2) learners unprepared: Five lecturers noted that the weakness in students' academic background makes it difficult to conduct discussions in class. For example,

This (interactive) approach may be suitable in Harvard or MIT but not applicable to our students because they are so weak in their academic background. (L7, L1)

- (3) constraint of teaching time: Four of the eight lecturers commented the interactive ways of teaching are time-consuming, and therefore they are not

applicable due to the time constraint. For example,

I have never tried, and I don't think it is feasible to introduce discussion in our classes because teaching time is so limited... If I had ever experienced this method, I would have more ideas about how it would work. (L1)

(4) large-class: Three lecturers noted that it is not possible to adopt it in a large class. For example,

Adopting in class discussion may be possible if we could limit our classes to have no more than 30 students. If we let students discuss concepts in class now (with the current size), this may become 'time for a rest' for them. (L8)

(5) teaching design/skills: Three lecturers noted that good teaching design, teaching skills are demanded to engage students in the discussion, and it will need a high level of teaching commitment to keep improving teaching technique. For example,

Discussion in class should be helpful for students' understanding, but lecturers will need to put much effort into the teaching design to stimulate student involvement in the activity. (Also) teachers must have good (teaching) skills to warm up the classroom climate. (L4)

With so many concerns about the existing barriers to applying the interactive teaching approach, only one lecturer mentioned his experience of attempting to break the didactic teaching.

I remember that I had conducted an in-class discussion about one concept question, and the students' response was satisfying. Our students may be reluctant to actively express their opinions in class, but if you ask them questions, and give opportunity to answer, most of the students will give you a response, and gradually, it can promote interaction in class... However, I have only tried once due to the pressure of covering the syllabus. (L6)

Although the lecturer received satisfying responses from his students, this experience still did not induce him to persist in making further modifications, yielding to the content coverage.

In summary, although none of the eight lecturers denied that discussion could be beneficial to students' learning, no one really adopted this approach as part of their regular teaching activities. The lecturers' focus on implementing an interactive way of teaching was on what reasons make it practically impossible

rather than why we need to adopt it. The lecturers' considerations and decisions indicated that they viewed modifications of the didactic teaching as auxiliary rather than as essential to improving their teaching. Compared with their strong criticisms of the current content selection, the lecturers seemed to have much less concern about the traditional teaching approach and the whole curriculum structure, which implies that they believe in a transmission view of teaching and learning.

Meanwhile, the lecturers seemed to emphasise on the external barriers provided by their students and the administration system, including (1) the insufficient background and motivation of the students and (2) the limitations of teaching time and student numbers. The lecturers seemed to have made no attempts to overcome these barriers, except to improve their teaching skills. The lecturers tended to isolate their teaching from students' learning, and the students' insufficient physics background and learning motivations seemed to be out of their control and responsibility while teaching.

5.4.2 Use of teaching-aids

The second topic of teaching approach was using teaching-aids. Six out of the eight lecturers agreed and no one disagreed that using some teaching-aids, such as demonstrations and videos, enables you to promote student interest. But five of them admitted that they have never applied them in their physics classes. The reasons for not using these teaching-aids are:

(1) time constraints, for example,

If the pressure of covering the syllabus can be reduced, I would like to bring a laser gun and show my students how a laser works when teaching optics. (L8)

(2) lack of equipment and facilities, for example,

If someone could provide the equipment [for demonstration], I would be glad to introduce it into my class. (L5)

(3) lecturers' attitudes, for example,

We (the physics center) bought four sets of the optics demonstration package last year. But no one ever took it to their classroom (to show to their students). Lecturers' attitude is a reason for not applying it; most lecturers are still accustomed to the traditional approach. (L1)

To summarize the above two sections, the main barriers to lecturers to introducing a new teaching approach, i.e. utilizing teaching aids and adopting an interactive teaching method, may be due to two main reasons:

- (1) lecturers' conservative attitudes of keeping the traditional styles of teaching and resisting trying something new,
- (2) lecturers do not see the value of applying a new teaching model.

Five months after the lecturer interviews, the researcher applied an intervention teaching which was devoted to an interactive way of teaching as well as utilizing several teaching-aids. The new teaching approach has received strong support from the intervention students. The results are discussed in chapters 8 and 9.

5.4.3 Views of teaching task

Many studies show the shortcomings of the traditional teaching approach, such as low achievement in developing students' understanding of physics concepts (eg, Hake, 1997) and encouraging rote learning (eg, Mazur, 1997).

However, in the interviews of the eight lecturers, no one criticized the unique-directional transmission or the learners behaving as passive receptors in the physics class. According to the lecturers' interviews, they seemed to limit their responsibility and teaching task to teaching only.

Five out of the eight lecturers emphasized that the responsibility of being lecturers is to their teaching. For example,

If you do not teach, they will never understand... Like vector integral, it is tricky for students. I have to work on several exercises on the blackboard to repeat the solving procedures to enforce their (mathematical) ability. (L1)

When I teach, I always work very hard (on the blackboard) to show them the solutions to the problems. Teaching is a work of conscience; students are our customers... (So), we have to work hard while teaching. (L5)

Although I have taught for over 20 years, I have never felt tired of this job. I still put much effort into searching for some interesting information to teach my students. I think this is our responsibility. (L2)

In our center, I believe all of our colleagues are very responsible. Some even teach extra hours to cover the assigned syllabus. (L1)

Only one lecturer mentioned that the students' learning outcome should be part of the lecturers' responsibility.

The other finding which was disappointing to the researcher was that none of the lecturers acknowledged their lack of understanding of the process of their students' learning, or expressed any desire to understand it.

Lecturers' perceptions of teaching are strongly influenced by the traditional model, which has been dominant in the education system in Taiwan for a long time. The so-called responsibility of the lecturers seemed limited only to teaching but not to learning. The lecturers may anticipate that learning will accompany automatically with teaching. From the above opinions, the classroom activity perceived by the physics lecturers is still dominated by the transmission format. This may imply that the fact that students behave as passive listeners in class, is acceptable to the lecturers, and the learning process can be left out of the classes.

Langenberg (1997) noted in the preface of the Proceedings of the International Conferences of University Physics Education (ICUPE):

If we are to be responsible for our students' learning and not just for our own teaching, we will need to pay more attention to understanding how humans learn than we have in the past.

The lecturers' perceptions of teaching approach were re-examined in lecturer survey to see if their thinking was altered by the students' comments (survey 2).

5.4.4 Survey results regarding teaching approach

In the survey, all of the seven physics lecturers were asked to select teaching activities which, in the context of helping learners, are:

(1) both beneficial to learning, and applicable to teaching implementation,

(2) beneficial to learning but with barriers to teaching implementation.

The alternatives which the lecturers were asked to choose, along with the results from the lecturers, are listed in Table 5.2.

Table 5.2 Lecturers' view of teaching approach in lecturer survey

Teaching strategies to benefit learning	applicable in teaching	had barriers in teaching
1. give hand-outs	1	0
2. give assignments	2	0
3. call on students to answer questions	3	1
4. adopt in-class discussion	2	7
5. guide students to a deeper approach	3	0
6. introduce examples from everyday life	6	0
7. monitor student learning habits	1	0
8. introduce hi-tech topics and occasional stunts	2	1
9. be concerned about student learning pace	1	0
10. give quizzes	3	0
11. adopt other teaching aids, e.g. _____	2	2
12. others	0	0

Two issues are discussed based on Table 5.2.

- ***Introduce examples from everyday life***

Lecturers' responses towards the first question were discrepant except for their agreement in introducing examples from everyday life. Providing life examples was regarded as a teaching approach which is beneficial to learning as well as applicable in implementation. The consensus of providing life examples has been in discussed section 5.2.4.

- ***Adopting in-class discussion***

With respect to physics lecturers' opinions, all of the seven lecturers selected in-class discussion, among the eleven alternatives, as beneficial to learning but with

barriers to implementation. The high consistency of agreement among the surveyed lecturers as to the importance of applying in-class discussion gives hope for a future shift from traditional lecturing to interactive teaching. However, the existing barriers perceived by the physics lecturers explain the absence of the methods in the current physics classes.

Interactive teaching methods have been shown to be an effective way of teaching, by numerous education studies (eg, Drew, 1990; Hake, 1997; Heller, Keith and Anderson, 1992; Redish, 1996). In-class discussion is one major model of interactive teaching (Mazur, 1996; Meltzer and Manivannan, 1996).

From lecturers' answers in the survey, major barriers preventing the adoption of discussion in physics classes are (1) large classes (50-70 students per class), (2) learners' attitudes, (3) time constraints. For example,

Many students may feel they have nothing to do because the lecturer will limit his/her attention to a few students. (L8)

Students are conservative about talking in public; and lecturers need much effort and skill to stimulate an enthusiastic discussion in class. (L4)

In-class discussion takes too much teaching time. (L5)

The lecturers' responses towards the teaching approach were consistent in both the interviews and the survey. They all emphasised the difficulty of trying an interactive teaching method.

In summary, the lecturers were found to limit their teaching responsibility and teaching task to simply giving lucid lectures. No links between teaching and learning were made in most of the lecturers' conversations. Meanwhile, the lecturers' attitudes towards modifying the existing didactic teaching approach appeared to be passive. Very few criticisms on the traditional unique-directional delivery teaching were found from the lecturers' responses. The lecturers expressed more concern with the existing barriers than with the potential strengths of adopting the interactive teaching approach. These barriers seemed to be beyond their ability and/or responsibility to overcome. The issue of teaching approach (how to teach) seemed to be subsidiary to that of content selection (what

to teach).

5.5 Lecturers' responses to improving the learning outcomes

In this section, lecturers' responses about improving the learning outcomes are discussed in four steps:

- (1) lecturers' perceptions of the students' learning outcomes,
- (2) learning barriers and the solution,
- (3) quality of the course versus learning interests, and
- (4) lecturers' attitudes towards the students' comments.

5.5.1 Lecturers' perceptions of the students' learning outcomes

A consensus from the lecturer interviews was that the students' academic performances were not satisfactory. Six out of the eight lecturers pointed out that most of their students' learning achievement was poor, and no opposing opinions were found.

When I marked their mid-term and final examination papers, I felt so sad that they could not solve some very simple questions. Some of those questions have been taught in class and should have been no problem for them as long as they had revised them... Looking at their answers, I realized that much of the effort I put into teaching them was wasted...Perhaps I will adjust my feeling (about the poor performance) when I teach for a longer time. (L6)

I think every lecturer would agree that these students' learning is poor, and in recent years I feel the problem has become more and more serious. (L2)

Lecturers' dissatisfaction with the students' academic performance helped to explain the high failure rate, which was about 20-30%. The prevalent problem of the students' poor academic performance in university physics is also noted in the literature mostly in the west (eg, French, 1988).

The next section will discuss the possible reasons for the poor learning outcomes, based on the lecturers' points of view.

5.5.2 Learning barriers and the solution

- *Main barrier is learning attitude and habits*

From the lecturer interviews, the major learning barriers they identified related to the students were learning attitudes and habits. These were said to be stronger barriers than learning ability such as academic background and aptitude.

Seven out of eight lecturers pointed out that learning attitude was a major reason for the poor learning, and five of them emphasised that weakness in academic background was only a subsidiary reason. For example,

When I teach, I assume that all my students have insufficient (academic) background, but I still expect them to learn well here. The key point is their (learning) attitude not their (learning) ability. Many of them have no sincere wish to enhance their knowledge at university; most of them do not have a regular study habit. They just want to pass and get a degree. (L2)

I think as long as the students care about this course, they can hardly fail. The examination questions are mostly very simple and many of them are the assigned problems. Those students have failed mainly because of their learning attitudes, most of them often skip classes. (L1)

Their (learning) attitude is the major problem. I think the (examination) questions have been simple enough. We have already considered their (weak) background, but many students are simply too indifferent...(According to our assessment standard), they won't fail unless they have never cared about this course. (L8)

The above quotes indicate that although the lecturers regarded the students' passive learning attitudes as a major barrier, the lecturers did not deny that the students' physics background was weak as well. Their conversations also implied that they have been "considerate" to the learners' weak background and lowered the assessment standard. Therefore, with respect to the low academic performance, the lecturers had adopted strategies of reducing the difficulty of the course. This strategy may not be appreciated by the students, since the difficulty of the course is only a minor barrier as perceived by the students (see section 4.5.3). The lecturers' and the students' views of the learners' background and the

difficulty of the course in retarding the learning of physics were not consistent. The strategy of lowering the standard may even result in unanticipatedly influencing the students, for example, deteriorate their awareness and commitment to learning.

Although it was found that both the students and the lecturers consistently regarded passive learning attitudes was a major reason for the poor academic performance (see section 4.5.3), the lecturers seemed not to consider or propose any strategies to eliminate this barrier.

At the same time, four lecturers mentioned that lack of aptitude for learning physics was also one reason for the poor learning, but they all emphasized that this problem is not major. For example,

As a lecturer, I hate to say this, but we have to admit that some students' (intellectual) ability really is not suitable to study in this (engineering) field. But I still do not think this is the main reason. (L7)

The lecturers' focus on learning habit and attitudes as the main barriers of academic achievements agreed with those of the students (see section 4.5.3). Their opinions also matched those of other researchers as well (eg, Abouserie, 1995; Biggs, 1996). These researchers argued that learning motivation plays an important role in learning strategy and thereby influences the learning outcomes.

- ***Solution: Teaching style can influence learning attitude***

In the interview, when the lecturers criticized the learners' low motivation and indifferent attitude to learning physics, their focus was limited to the learners themselves. Many lecturers were not aware that their role as a lecturer can be influential on learners' attitudes, through participating classroom activities. Promoting learning motivation and commitment seemed to be auxiliary to the lecturers in fulfilling their teaching responsibility, when compared with the subject matter.

Education research has shown that the learning environment, carried by the lecturers, is perceived by the students to alter learning attitudes and result in

different learning outcomes (Ramsdon, 1992; Trigwell and Prosser, 1991). Several studies found that students' perceptions of the teaching style was more consistent with what the students preferred, their learning outcomes appeared to be better (eg, Fraser and Wubbels, 1995; Fisher, Fraser and Barry, 1983).

In this research, the students' learning attitudes was found to be substantially deteriorated while studying university physics (see section 4.5.2). Though this depressing result is not a unique case (eg, Redish, Steinberg and Saul, 1998), it is a warning sign. The teaching style provided by the physics lecturers may not just be unable to encourage but may even discourage students' engagement in learning. Prevalent student impressions of the university physics courses are that they are boring, lacking in relevance, lacking in interaction, and frustrating (see section 4.3.1).

Based on the findings of the students' opinions, establishing the learners' interest in learning physics appeared to be an important teaching task for improving the learning outcomes. However, during interviews, some lecturers seemed to imply that consideration of learning interest may compete with the maintenance of the quality of the course (eg, section 5.2.3).

5.5.3 Quality of the course versus learning interests

The lecturers' views about the issue of interest versus quality were investigated in both the interviews and the survey. The results are discussed as follows.

- ***Quality and interest: : Friends or foes***

In the interviews, five of the eight lecturers seemed to be concerned about the feasibility of putting effort into improving students' learning interest. For example,

Yes, there are many ways to make physics classes more interesting, but one thing I would always insist on is: we have to keep the standard [quality] of our teaching. Otherwise students from our university cannot compete with those from other universities. (L7)

I know there are many ways to attract them; those are all good. But unless we can have extra teaching time, there is nothing we can really try.... We have

so much material to teach already... There are no ways we can solve this [cold climate] problem. (L1)

I know what (topics) students like to listen to in class. We had better start with them to keep their attention... However, when I shift my teaching topics back [from their life] to physics theory or mathematics, many students lose their concentration quickly... Reasoning ability is so important to them in the future, but they just don't understand [the importance]... They show interest in anything except physics [theories]... I have to make compromises with them in my teaching. (L2)

Although no one clearly claimed that insisting on the maintaining quality of the course can hurt the students' interests, many of them worried that stimulating the learners' interests may hurt the quality of the course. From the lecturers' descriptions, many of them seemed to equate the quality of the physics course with dull, abstract theories and tough mathematics. Their opinions also imply that making this course more attractive to students will have to lower the standard of this course in return.

The perception of the lecturers is of course mismatch to the literature. Many other studies showed that higher learning interest was usually accompanied with better learning achievement (eg, Tobias, 1992).

The lecturers' attitudes about this issue were further investigated in the lecturer survey, to acquire a better understanding.

- ***Quality and interest: Which is the priority.***

During the lecturer interviews, some lecturers argued that if learners' interest is promoted, the teaching design may lower the quality of the course. These arguments imply that the quality of the course could be sacrificed to learning interest. With respect to this issue, physics lecturers' responses in the survey are discussed with respect to the three questionnaire questions.

(1) Whether the consideration of quality of the course and that of learning interest are competing?

Three lecturers answered "no"; two lecturers answered "yes", and other two did not specifically answer. Therefore, no consensus was reached among the

lecturers. The responses were not very different from those of the interviews. Some quotes are listed below.

No, they won't be in conflict, since only when the students have interest in learning can the quality be achieved. (L6)

Yes, since promoting learning interest is time-consuming, it will result in reducing teaching content. Therefore, if we want to deal with both (of the interest and quality), the only way is to extend our teaching time. (L3)

(2) Whether interest or quality should be a superior consideration in the teaching design?

All of the seven lecturers answered that the consideration of promoting learning interest is more important than maintaining the course quality. Some physics lecturers also noted that more resources are needed both in teaching materials and teaching aids in order to promote learners' interest.

Making our students feel interested in learning physics is much more important than the quality (course). The question is different levels of students have different interests; which level of the students should we focus on? (L7)

The consensus among all lecturers in emphasising the importance of learning interest seemed not to match very well with the students' evaluation of the course (see section 4.2.1). Based on the mismatch, the lecturers were asked their opinions in the next question.

(3) Many students (from survey 2B) responded that the course was too boring and irrelevant to life. Do you think the purpose of the students' responses were to improve their learning outcome or just to have an easy time in class?

Six out of the seven lecturers answered that most of the students' responses were based on learning outcome, and one noted "neither, students' responses were just to reflect what they feel."

The results imply that most students' opinions were worthwhile investigating.

In summary, the lecturers' opinions imply that the existing teaching design needs adjustment to promote learners' interest. However, many of the lectures may face

a dilemma in dealing with the issue of quality versus interest.

To improve the learning outcomes, the students' opinions may play an important role in helping the lecturers understand their expectation. Also, to examine the consistency of lecturers' perceptions and through the students' views towards the existing teaching. Lecturers' responses to the students' evaluation of the existing course are discussed in the next section.

5.5.4 Lecturers' attitudes towards the students' comments

As mentioned in section 4.3.2, strong complaints from the students about the existing university physics course design were found in this research, and the researcher attempted to bridge the gap between the lecturers and their students by providing some of the students' results to the lecturers. Two questions about the lecturers' views of the students' opinions are discussed:

- (1) Did the lecturers believe that the research results from the students were reliable?
- (2) What were the responses of the lecturers to the students' comments?

- ***Reliability of the research results***

In the lecturer survey, six out of the seven lecturers commented that they regarded the questionnaire design of student survey 2 as reliable. They agreed that the connotation of the questionnaires was neutral, and the researcher did not show any attempt to guide the participants (the students) to expected responses. For example,

The majority of the students' opinions were reliable, but not all of them. This survey should omit the students who skip classes often. This kind of students' response is not worth collecting. (L3)

Concluding from the above lectures comments, most of them agreed that the research design of student survey 2 was reliable, and the students have expressed their genuine perceptions of the university physics course in survey 2, which were mainly hoping to improve their learning outcomes.

In the lecturer survey, all of the seven lecturers agreed that the students' opinions (survey 2) provided by the researcher were worthwhile and can help to improve their teaching.

- ***Attitudes to improving their teaching***

With respect to the student comments in survey 2, five out of the seven lecturers merely answered that there were no surprises. One lecturer queried the divergent responses to the question of *repetitive content* by students in different classes. He felt that the responses should have been more consistent because all of the lectures have to adhere to the unified system. Therefore none of the lectures raised the issue of the overall course design. The fact that high percentages of students expressed their dissatisfaction (in survey 2) with the learning environment (see section 4.3.2) seemed either not to surprise the lectures or they intentionally ignored it. High demands implied from the student survey (survey 2) for a change to the existing curriculum: content design and teaching approach, seemed unable to induce the lecturers' enthusiasm for teaching reform.

In answering to the question of how did the lecturers think of improving the teaching and learning, they mentioned existing barriers more often than productive opinions for improvement. Some quotes are listed below:

(1) The existing barriers:

Teaching time is too limited, and assigned content is too heavy... Also, the hot weather is harmful to the learning motivation. (L3)

Demonstration can promote the learning interest. If we could establish multimedia facilities in our class, it could benefit the learning outcome. (L5, L2)

Many good ideas cannot be applied because of the large class. (L8)

(2) Suggestions for improvement:

Understanding what the students feel, and promoting their learning interest is also important. (L4)

Be aware of our students' academic background. (L7)

Introduce demonstration and discussion in our teaching activity. (L6)

The above opinions implied that the lecturers hold a positive attitude towards the design and results of this research, while their attitudes towards the students' criticisms and their intention of improving teaching and learning in the university physics course were found to be fairly passive.

In summary, the lecturers acknowledged that the students' academic achievement was far below satisfaction. The lecturers were also found to adopt a strategy of lowering the assessment standard to avoid failing too many students. Most of the lecturers' attitudes regarding promoting learning motivation were reluctant since they considered that efforts to promote learning motivation may conflict with the maintenance of the quality of the course.

With respect to the learning barriers, the lecturers pointed out the passive learning attitudes, the weak physics background, and the lack of intellectual ability for learning physics as the main reasons for the poor outcomes. The lecturers' opinions implied that most of the lecturers regarded learning physics as a task of highly demanding cognitive operation, where affective dimensions play a beneficial role. However, no responses were found from the lecturers to link learning physics with the need for the students' participation in social practice processes in class. According to the sociocultural view of learning, the students fail to construct scientific concepts maybe partly because they have not been acquainted with the "culture" of the scientific society, such as using the scientific symbols, using graphs, understand the subtle differences of the words between scientific and everyday life usage, and/or the focus of learning physics. The sociocultural view of learning may be far beyond the physics lecturers' perspective.

The next section will discuss the lecturers' attitudes towards pedagogical knowledge and education research.

5.6 Influence of education research on lecturers' teaching

As mentioned before, most of the lecturers are lacking in pedagogical knowledge. With excellence in subject knowledge in contrast to almost total absence of pedagogical background, how can the education research influence the lecturers' teaching? The lecturers' responses will be discussed under three headings:

- (1) lecturers' attitudes towards pedagogical knowledge,
- (2) education research as a bridge between lecturers and learners, and
- (3) education theory can broaden the lecturers' perspective.

5.6.1 Lecturers' attitudes towards pedagogical knowledge

As a result of communicating (interview, survey, seminar, and casual conversation) with the physics lecturers, the researcher realized that education theory is an unpopular topic, while other more practical issues, such as demonstration resources, tips for teaching skills and results of student surveys, were usually inspiring.

For example, the researcher gave a presentation to the lecturers in Feng-chia University in 1998. The presentation started with a brief introduction of pedagogical theory, i.e., various learning models, then gave an interpretation of the results of student surveys and ended with a short introduction to some trials of a new teaching model in university physics courses as reported in the literature. During the seminar, the participants engaged in much enthusiastic discussion about the research results, i.e., the existing problems, and had some concern about possible methods to solve the existing problems. No one had any comments about the pedagogical theory. After the seminar, many of the lecturers asked for copies of the statistical results, but no lecturers asked for reference articles.

In the survey, a question asked the lecturers for suggestions and comments about the student survey (2B). Lecturers argued about resources in the teaching environment including teaching time, teaching facilities and class size, as well as teaching skills. But the education theory is not one of their concerns.

According to the lecturers' responses, physics lecturers tend to regard teaching as a technique, and some regard it as an art (from interview). But few of them realise that education is a discipline, the same as physics with its theory basis; and that researchers are continuing to enrich the knowledge. Physics lecturers may devalue or may not even believe any of the education theory.

The importance of education theory to teaching and learning in practice are discussed below. In order to improve the teaching of university physics, promoting the status of education theory in physics lecturers' mind becomes a preliminary task.

The physics lecturers' ignorance of education theory was commented on in the literature. For example, Hammer (1996) criticised the fact that physicists do their research carefully following physics theories, but most of them teach physics only by intuition and experience.

5.6.2 Education research as a bridge between lecturers and learners

Besides providing the pedagogical knowledge, education research can also provide a bridge to help lecturers to understand their students and resulted in modification in their teaching design.

During 1997, the researcher advised the results of the student surveys to these physics lecturers by a seminar and by mail respectively. These surveys focused on students' expectations and perceptions of the teaching content, teaching approach and their learning barriers. These results may have diminished the gap between lecturers' perceptions of their students' thoughts based on their teaching experience, and the real perceptions in the students' mind. The adjustment in teaching content design in 1998, i.e., reducing content coverage, providing more examples in everyday life, may be a response to the criticism implied from the student surveys. This adjustment matched the students' expectations (see section 4.3.1).

The researcher humbly suspects that the results of this study may have made

some contributions to promote the lecturers' understanding of their students.

5.6.3 Education theory can broaden the lecturers' perspective

Physics theory can widen physicists' perspectives about how the physical world works. For example, Newton's Law of Gravitation enabled us to move from a picture of two-dimensional symmetry to a picture of three-dimensional symmetry, and Einstein's Relativity has extended our perspectives to four and more dimensional symmetry (Dirac, 1963). N-Dimensional symmetry has now become commonly accepted knowledge amongst physicists.

Similarly, education theory can also widen lecturers' perspectives of teaching and learning. For example, a constructivist view of learning has changed our understanding the process of learning from one of passive absorption to one of active construction; this notion makes the teaching task much more profound and complex than what people previously thought (Shulman, 1987).

Gibbs (1995) claimed that "learning how to learn" is based upon conceptions and knowledge of learning tasks, and not on techniques. His notion can be referred to teaching; improving teaching based on broadening the perspectives of teaching instead of simply technique training (Hammer, 1995).

5.7 Summary of the lecturers' points of view

According to the lecturers' responses found in this research, several findings are summarised below.

Firstly, the lecturers tended to limit their teaching task to teaching rather than learning. The dissatisfaction with the students' academic achievement (see section 5.5.1) seemed not to challenge the lecturers' belief in the fulfillment of their teaching responsibility (see section 5.4.3).

Secondly, the lecturers were found to hold a transmission view of learning. They tended to be more concerned about what to teaching (the content) rather than how

to teach (the approach) regarding improving current teaching outcomes (see section 5.4.5).

Thirdly, regarding the aims of the course, the lecturers focused only on the cognitive aspect, ie, physics knowledge and thinking ability (see section 5.2.2). The learners' emotional consideration, which includes learning motivations and perceptions/beliefs of learning physics, seemed to be isolated from the aims of this course, although the lecturers had pointed out the problems of the students' low learning motivation (see section 5.2.3) and inappropriate perceptions of learning physics. These perceptions of learning physics included why to learn (see sections 5.2.2 and 5.3.2), how to learning (see section 5.4.1), and what (see section 5.2.3) to learn.

Finally, when discussing the issues of improving teaching and learning outcomes, the lecturers' foci were limited to technical aspects rather than theoretical aspects. That is, the pedagogical theories contributed by education research seemed not to be able to provide facilitation in improving their teaching.

Chapter 6

A summary of students' and lecturers' opinions

In chapters 4 and 5, the students' and the lecturers' views were discussed in the areas of course design, teaching, and learning. In this chapter, the opinions of the two groups will be summarized along with education researchers' views. The summary in this chapter seeks to provide a deeper insight into the existing situation in university physics education in Taiwan, and then lead to possible ways to improve the existing situation.

Four main points are discussed in this chapter:

- (1) agreement between students and lecturers,
- (2) disagreement between students and lecturers,
- (3) paradoxes found from the responses,
- (4) conclusions of the existing situation and suggestions for modifications.

6.1 Agreement between students and lecturers

There is some agreement between the students' and the lecturers' views found in this research. In comparing the responses of the two groups, several points appeared to be consistent. They are:

- (1) dissatisfaction with learning achievement,
- (2) poor affective learning outcomes,
- (3) transmission view of learning.

6.1.1 Dissatisfaction with learning achievement

The first agreement between the students and the lecturers was that they agreed that the learning achievement was not satisfactory.

Many lecturers pointed out that the learning achievement was ~~not satisfactory~~ (see sections 5.5.1 and 5.5.2). They also implied that the assessment standard had already been adjusted to cope with the students' academic backgrounds, but the failure rate still remained as high as around 30%. With respect to the students, they seemed to have no objection to the high failure rate. Very few students commented on the high failure rate, in contrast to the strong and consistent concerns about other issues of the teaching design, such as the content selection (see section 4.3.1). The students' seemed to accept the fact that they have poor academic performance indicated by their grades. At the same time, as low as less than one third of the students agreed that they achieved the goals which they valued most from this course, including basis for advanced study, applications of life, and contemporary technology (see section 4.1.3). The low agreement of these items indicated the students' disappointment with their learning achievement from this course.

In conclusion, it was found that both the students and the lecturers perceived the learning achievement is unsatisfactory.

6.1.2 Poor affective learning outcomes

The second consistent response found from the students and the lecturers was related to the poor affective learning outcomes. In addition to the problem of dissatisfaction with academic achievements, the responses about affective learning outcome appeared to be even more negative. Section 4.2.1 shows that significantly more students selected the negative affective statements, which included teaching very boring, not appealing, and failure to promote learning interest, than the positives, when evaluating the course. At the same time, the responses to the open-ended questions indicated more feelings of boredom than of interest, and more suffering than enjoyment (see section 4.3.1). Moreover, the number of students who held a passive attitude of minimum effort to pass increased dramatically during the learning process (see section 4.5.2).

From the analysis of the lecturers' views, in section 5.3.1, it can be seen that many lecturers acknowledged that they felt it was hard to stimulate the students' participation in classroom activities, and that the classroom had become a stage for a solo performance rather than a place for learning practice. The students seemed to behave as passive, or even indifferent, audiences in physics classes. The lecturers' comments about the lack of interaction in class was in accordance with the students' comments on the boredom and monotony of the university physics course.

Regardless of the reasons for, and without wishing to consider responsibility for these frustrating results, poor affective learning outcomes were perceived by both the lecturers and the students. The course seemed to push the learners away from physics rather than attract them to it.

6.1.3 Transmission view of learning

The third consistent perception found from both the lecturers' and the students' perceptions was that both groups hold a transmission view of learning.

When the lecturers discussed the problems of the lack of student participation in class, they tended to search for modification to the content design rather than adjustment to the teaching approach (see section 5.3.4). The traditional didactic teaching seemed not to be questioned from the lecturers' stance. Also, when the researcher actively raised the issue of adjusting the teaching approach to promote interaction between the lecturers and the students, the lecturers' responses focused more on the existing barriers than on the potential strengths that a more interactive teaching approach might bring to learning outcomes (see section 5.4.1).

With respect to the students' views, more concerns were found to focus on content design, such as covering too much, too theoretical, rather than on the didactic teaching approach with its lack of interaction between the students and the lecturer (see section 4.3.1).

Therefore, the two groups seemed to be more concerned about modifying the teaching content than adjusting the teaching approach when thinking about improving the teaching and learning of the course. In other words, they were more

concerned with what (content) to teach than how (approach) to teach.

The lecturers' and the students' superficial views of the learning process are also reflected in the lecturers' responses to the teaching responsibility and the students' perceptions of conditions for a good teaching performance. The lecturers emphasised their responsibility in teaching as being mainly devoted to searching for useful/interesting teaching information and putting their efforts into giving lucid lectures in class (see section 5.4.3). Similarly, the students indicated that giving a lucid lecture and having a strong academic background were perceived to be the most important factors for being a good physics lecturer, while encouraging discussion and providing alternative teaching methods were regarded as trivial for lecturers (see section 4.4.1).

In conclusion, for both the students and the lecturers, the responsibility of teaching seemed to be limited to teaching rather than engaging learning. Teaching tasks and learning outcomes appeared to be independent. Therefore, both of the two groups were found to hold a superficial transmission view of learning.

The above four sections have discussed areas of agreement between the two groups. The next section will discuss the areas of disagreement between them.

6.2 Disagreement between students and lecturers

The opinions of the students and the lecturers were mismatched mainly in three areas:

- (1) teaching goals and content selection,
- (2) learning barriers, and
- (3) attitudes toward teaching innovations.

6.2.1 Teaching goals and content selection

Opinions about teaching goals and content selection were mismatched between students and lecturers, especially in the aspects of focus and coverage.

Firstly, the students tended to be more concerned about practical benefits from learning university physics, while the lecturers focused more on the subject knowledge itself. In section 4.4.1, among the students' expectations of the teaching goals, application examples linked to everyday life and knowledge basis for majoring courses were perceived to be the most important learning goals by the students. Although the lecturers agreed that the teaching content design should show the students the relevance of physics to everyday life and careers, they pointed out that some other teaching goals should be regarded as being more important. In section 5.2.2, the physics lecturers expressed the opinion that the most important teaching goals were to enhance the students' understanding of physics concepts overall and to develop the students' thinking ability. The lecturers also criticised the students' narrow perspectives, wishing the students would not be limited to short-term and practical usage only when viewing the goals of the course. Therefore, what the lecturers emphasised was not what the students valued.

Secondly, excessive content coverage causing an unreasonably fast teaching pace was a great concern of the students. The teaching pace was found to be the students' very first concern regarding the existing course design in both the open-ended (see section 4.3.1) and closed (see section 4.2.1) questions. A drastic reduction in content coverage was demanded by the students. This student complaint may not be surprising to many of the lecturers. Although a few lecturers expressed their concern about the current design making them continue teaching without matching the learners' ability, there was a lack of consensus amongst the lecturers about the issue of reducing the content coverage (see section 5.2.3). Most of the lecturers may face strong pressure from their own perceptions of teaching responsibility if they want to reduce the coverage.

Therefore, the students' expectations of greatly reducing the teaching content were mismatched with the lecturers' considerations.

6.2.2 Learning barriers

The second discrepancy in opinions between the lecturers and the students concerned the barriers to learning university physics. Although both groups admitted that the students' academic performance was not satisfactory, they gave

different interpretations of the major causes for the learners' poor performance. The differences can be discussed in three areas.

Firstly, the lecturers paid more attention to the students' weakness in high school physics background than did the students. Many lecturers pointed out how poor the students' standard was, and explained their teaching strategy of reducing both the difficulty and the challenge of the course in order to match the students' level (section 5.5.2). However, the difficulty of the physics subject seemed not to be a major concern for most of the students. The students' concerns about the course being too difficult were much less than their concerns about it being too fast and too boring. These responses were consistent in both the closed (see section 4.2.1) and the open-ended (see section 4.3.1) questions. Therefore, difficulty in understanding physics concepts appeared to be only a minor factor contributing to the unsatisfactory academic performance, as far as the students were concerned.

Secondly, the barrier of the English version textbook to learning university physics seemed to concern the students, in contrast to the complete neglect of this issue by the lecturers. The problem of reading the English textbook was perceived by the students to be more serious than the difficulty in physics (see section 4.5.3). The lecturers may not realise the existence of this problem, or may regard the English barrier as beyond their responsibility as physics lecturers.

Thirdly, the students' affective responses were perceived to be a major barrier in learning the course by the students, while lecturers focused more on cognitive considerations. The students' agreement that the course was very boring, irrelevant, and monotonous was high (see section 4.2.1), and also showed significant links to the deterioration in learning attitudes and academic performance extrapolated from the correlations (see section 4.2.3). Promoting student learning interest seems to be an essential task for improving academic achievement.

With regard to the lecturers views, although some of them noted the importance of the students' interest in order to engage in the learning process, many of the lecturers worried that efforts to stimulate learning interest might sacrifice the standard of the course (see section 5.5.3). Even though a few lecturers did not hold an opposing view towards learning interest and course standard, they viewed

the need to promote interest as subsidiary rather than primary when considering their teaching tasks.

Therefore, the lecturers were found to be rather passive in contrast with the students' high level of concern about the affective outcomes of learning physics.

6.2.3 Attitudes towards teaching innovations

The third discrepancy in opinions between the students and the lecturers was in their attitudes towards teaching innovations.

The students expressed their great disappointment about their learning performance and the course design in the closed questions (see sections 4.2.1 and 4.3.1). The negative attitudes were even stronger in the open-ended questions of the questionnaire, where the positive comments were less than one third of the negative (see section 4.3.2). The only aspect of the course, which received a positive response from the students, was that the course was worthwhile.

Therefore, while the students seemed not to deny the value of the course, they delivered strong criticism about the course design. If these negative responses could be interpreted as a signal from the students to the lecturers that they expect teaching innovations, then strong dissatisfaction with the existing course design then must indicate strong expectations to see a change in the future.

However, based on their responses, the lecturers' opinions were rather more conservative than those of the students. Most of the lecturers' responses to questions regarding improvement to the teaching and learning, focused more on the existing barriers caused by the lack of teaching resources, such as time constraints, and lack of teaching facilities, rather than on the necessity for innovation in teaching design (see section 5.5.4).

The lecturers may yield to the existing constraints and accept the current poor learning outcomes. Meanwhile, since most of the lecturers were found to confine their responsibility to teaching only, they may consider that the unsatisfactory learning outcome may not challenge the fulfillment of the teaching responsibility. Therefore, the attitude of most lecturers regarding teaching innovations was conservative and passive.

6.3 Paradoxes found from the responses

The third point to consider when summarising the students' and the lecturers' views are the paradoxes found in the opinions of both groups. Clarification of these paradoxes can help to develop a better understanding of the existing situation. A better understanding can in turn help identify possible ways to improve. The paradoxes found from both groups are discussed below as three points:

- (1) performance inconsistent with opinions,
- (2) satisfactory teaching along with poor learning, and
- (3) teaching efforts/strategies may deteriorate learning.

6.3.1 Performance inconsistent with opinions

The first paradoxical finding was a mismatch between the opinions and actual performance, of both the students and the lecturers.

The incoming students had expressed their high self-expectations and learning motivations in the survey, whereas these positive opinions were found to be widely discrepant from their actual learning commitment, in terms of their study hours and learning strategies (see section 4.5.2). Meanwhile, when many students expressed their criticisms of the boredom and repetition of the course, their academic performance was found to be far from satisfactory. This shows a significant mismatch between how the students feel/think and how they actually behave. Thus, it may be problematic to simply investigate people's opinions without observing their actual behaviour.

Similar conflict was also found with the lecturers. When the lecturers emphasised the passive learning attitudes as the major learning barrier on the one hand, on the other, they did not regard eliminating this barrier as an important task when discussing the improvement of the teaching design. Their teaching design was in fact contributing to the deterioration of learning motivation as perceived by the students (see section 4.5.2). Meanwhile, it was found that many lecturers strongly expressed their criticisms of the unreasonable content coverage and the unified

system, a situation which has remained unchanged for more than ten years. Their compromise and/or ignorance in responding to the existing situation were not consistent with the strong criticisms expressed in the lecturer interviews.

In summary, it was found that the attitudes of both the students and the lecturers were stronger when expressing opinions, than their actual behaviour, which appeared to be much more passive.

6.3.2 Satisfactory teaching along with poor learning

The second paradox was the satisfaction with the teaching commitment and the teaching performance in contrast to the dissatisfaction with the learning outcomes. This paradox was apparent in both the students' and the lecturers' comments on the teaching and learning of the course.

With respect to the students, they gave a positive evaluation of the lecturers' ability and teaching performance in the closed questions (section 4.4.2). In the open-ended questions, many students stated their appreciation of the high teaching commitment their physics lecturers showed in class (see section 4.3.1). However, the positive appraisal to their lecturers was ironically in contrast with the students' self-evaluation of their low learning achievement.

The students' "generous" evaluation of the lecturers was also found in the lecturers' evaluation of themselves. Many lecturers emphasised that all the physics lecturers in the center were highly committed to teaching. From the lecturers' point of view, their responsibility is limited to teaching, and therefore, the students' dissatisfaction with their learning outcomes did not challenge the fulfillment of their responsibility as lecturers.

Therefore, both groups possess conflicting images of teaching performance and learning achievement. Both groups seemed to view teaching and learning as independent factors, and the responsibility of learning outcome seems to belong to the learners alone. The satisfaction with the teaching performance and commitment may actually retard any attempt to put effort into improving the learning outcomes.

6.3.3 Teaching efforts/strategies may deteriorate learning

The third paradox was that some efforts/strategies that the lecturers made/adopted may deteriorate learning. When comparing the opinions of both groups, it was found that some teaching efforts/strategies may not only be ineffective, but may even retard the learning outcomes.

The first teaching effort that may retard learning is the effort put into content coverage. According to the lecturer interviews, many lecturers emphasised that working hard on lecturing and coverage of content are indicators of teaching commitment.

However, problems may arise as a result of this effort to cover the content. The lecturers may continue with the teaching material, and therefore, they may need to keep talking and writing, and deprive the class of chances for interaction in return. Meanwhile, attention to the learning may be sacrificed when the lecturers are devoted to covering the teaching content.

Due to the teaching task of content coverage, a number of possible disadvantages to learning may have resulted. Lecturers continuing talking may deteriorate learning interest and concentration. Meanwhile, lecturers devoted to teaching may make the lecture become a solo performance and fail to engage the students in both the cognitive process and social practice. The students may simply passively collect information rather than participate in learning. Moreover, the fast teaching pace may hinder the students' attempts to search for a deep understanding and so encourage superficial learning strategies. As a result, the students may only end up with knowing a lot of terms, without understanding the meanings or concepts of these terms. In fact, this type of low-level learning was criticised by many lecturers in the interviews.

As a result, low learning interest, low learning engagement, and a superficial learning approach may provide reasons for the poor learning achievement.

The second teaching effort that may retard learning is the strategies that the lecturers applied to assessment, including reducing the standard of assessment and disclosing the test bank to the students, yielding to the students' weak physics

background and low learning motivation (see section 5.5.2). These strategies were hoped to avoid undermining the students' learning confidence and encourage their learning commitment. However, these assessment strategies also reduced the required cognitive engagement mostly to the level of recalling only, ie, to remember the theory verbatim and to be familiar with the solution procedures of those problems in the test bank.

These assessment strategies applied by the lecturers may seriously misguide the students into adopting a superficial learning approach, and result in the prevalent problem of rote learners existing in all classes (see section 4.5.2). Meanwhile, the original aims of these strategies were also found to be unsuccessful based on the low study hours, and the passive learning strategies (see section 4.5.2).

Therefore, lecturers need to be aware that some teaching efforts/strategies may actually deteriorate the learning outcomes. When the lecturers complained about the students' low engagement, superficial learning, and poor learning performance, they should also be aware that their teaching strategies might unintentionally contribute to these problems.

Possible ways to diminish the above paradoxes and to improve the learning outcomes are discussed in the next section.

6.4 Conclusions of the existing situation and suggestions for modifications

In this section, a conclusion is reached regarding the understanding of the existing situation from both the students' and the lecturers' perspectives. In addition, some suggestions for modifying teaching to improve the learning outcomes are presented. Three points will be discussed:

- (1) the strengths and the weaknesses of the course,
- (2) shifting the class focus from teaching to learning,
- (3) perception rather than technique.

6.4.1 Conclusions: Strengths and weaknesses

Based on the responses of both the students and the lecturers, some strengths as well as weaknesses were found.

- *The strengths*

With respect to the lecturers, they have demonstrated their teaching commitment as well as a strong academic background to the students in class. Most of the students agreed on and appreciated these two strengths. Therefore, the students gave a positive personal appraisal of their lecturers.

With respect to the students' situation, two main strengths were found. Firstly, the incoming students had a positive learning attitude and high self-expectations for the new stage of learning in university. Secondly, the students' high school physics background on average was much higher than that of American students, and therefore, the difficulty of learning university physics was perceived to be acceptable by most of the students. However, these two strengths of the students were not perceived by the lecturers, who emphasised the weak background and negative learning attitudes as their major concerns.

Unfortunately, these strengths seemed not to benefit the learning outcomes. The efforts/strategies that the lecturers adopted appeared to be more likely to misguide the students in their learning approach. Also, the original positive learning attitudes seemed far beyond how the students actually performed.

These strengths may have been overwhelmed by the existing weaknesses.

- *The weaknesses*

Four major weaknesses emerged from this research:

Firstly, the students' high self-expectations did not match their actual implementation in learning in many aspects, including learning effort, learning approach, and achievement. The learning process seemed to deteriorate the original learning attitudes.

Secondly, the course design was inconsistent with the students' expectations and

their learning pace. When the students evaluated the course design the negative responses were much more than the positive responses. According to the students' responses, the major problems with the course were that the pace was too fast, the content was irrelevant, and there was a lack of interaction in the teaching.

Thirdly, as a result of the above two weaknesses - negative learning attitudes and unsatisfactory course design, poor learning outcomes are to be expected. Both the cognitive and the affective aspects of the learning outcomes appear to be frustrating to both the students and the lecturers. The teaching not only failed to enhance the students' understanding in physics, but also may have pushed them away from exploring the physical world.

Finally, both of the two groups seemed to have a superficial understanding of the learning process. They viewed the learning process as merely a process of transmission rather than one of construction. Their viewpoints ignored the complexity of the learning process. Based on their superficial views, the importance of the learners' role and learning motivation in teaching design were de-valued, and hence, they may feel that there is no need to modify the current didactic way of teaching.

The strengths and weaknesses of the existing situation as identified by this research are summarized in Figure 6.1.

The strengths	The weaknesses
<ul style="list-style-type: none"> ● <i>Students</i> <ol style="list-style-type: none"> 1. High original self-expectations and positive learning attitudes 2. Academic background better than the US students ● <i>Lecturers</i> <ol style="list-style-type: none"> 1. High teaching commitment 2. Strong academic background 	<ol style="list-style-type: none"> 1. Passive learning attitudes in actual learning implementation 2. Students gave negative evaluation of the course design 3. Dissatisfying cognitive & affective learning outcomes 4. Over-simplification of the learning process: transmission views of learning

Figure 6.1 A summary of the strengths and the weaknesses of the existing

Based on the above understanding of the strengths and weaknesses, and referring to the literature, there were several ways to improve the existing situation. Four suggestions are discussed below.

6.4.2 Shifting the class focus from teaching to learning

The first suggestion is to shift the focus of the class from teaching to learning. According to the lecturers' responses, the current physics class may be a typical teacher-centered class where the students' participation in the learning process is mostly ignored. Reasons for the shift of focus from teaching to learning are:

Firstly, the lecturers need to have a better understanding of how their students think, feel, and expect of the course and their learning. According to this research, the lecturers may not understand their students as well as they thought. The lack of understanding of the students' situations may become a critical factor in retarding the teaching and learning outcomes. A more student-centered teaching approach may help the lecturers to obtain a better insight into their students' situations, such as major learning barriers, etc.

Secondly, a shift from teaching to learning may help the students to be more

aware of, and become more independent in, their learning, ie, to promote the ownership of their learning. As found in this research, what the students expected to do for their learning is widely mismatched with what they actually did. Promotion of learning awareness is needed in order to improve learning outcomes.

Thirdly, the traditional didactic way of teaching was found to be ineffective both in promoting learning motivation and in enhancing academic performance in physics. Lecturers need to engage these engineering students in cognitive processes as well as social practice in learning physics in the classroom in order to achieve better learning outcomes in terms of better comprehension of physics concepts, promoting a positive attitude towards physics, and being acquainted with the “culture” of the science society.

Therefore, the focus of the physics class needs to be shifted from the lecturer and his or her teaching material to the students and their learning process.

6.4.3 Perception rather than technique

The other suggestion to improve the teaching outcomes is that perceptions are much more crucial than merely improving techniques for both the students and the lecturers in regard to improving teaching and learning physics.

This research has found that both groups' perceptions of teaching and learning were superficial compared with those of the education researchers. Both of them were found to over-simplify the learning process, and thus tolerated the passive learners in class and isolated teaching performance and learning outcomes. This superficial perception may have guided the two groups in an inappropriate direction regarding improving the learning outcomes, such as focusing on content selection only.

With respect to the aims of the university physics course, the students' focus on short-term benefits, such as relevance to their major, were criticised by the lecturers as a narrow perspective. This narrow perspective of the students may retard their learning motivation when learning the topics, which appeared to not to have practical usage. However, a similar problem was found with the lecturers, according to the researcher's view. It was found that the lecturers limited the aims

of the university physics course to the cognitive aspect only, ie, development of physics knowledge and thinking ability. Promoting the students' learning motivation as well as developing the students' perceptions of why and how to learn physics seemed to be beyond the scope of the aims of the course.

Meanwhile, the three paradoxes discussed in section 6.3, namely, inconsistency between performance and opinions, satisfactory teaching along with poor learning, and teaching efforts, which may deteriorate learning, can also be contributed to the lack of a wider and deeper perspective. Owing to the limitations of their perceptions, both the lecturers and the students may have not noticed some of the problems discussed above or have adopted inappropriate strategies to eliminate some of the problems.

In order to improve the learning outcome, both groups' perceptions need to be developed. Learning physics is more complex than simply receiving and storing physics knowledge, and improving teaching is more sophisticated than an accumulation of techniques. The lecturers need to be convinced of why to apply before knowing how to apply the teaching approaches claimed by the researchers to be the most effective. Similarly, the students need to develop their perceptions of why to learn university physics and the essentiality of playing an active role in the learning process.

A trial to improve the university physics education was carried out as a part of this research. Details of this intervention teaching design are discussed in the next chapter.

Chapter 7

Design and implementation of the intervention teaching program

The existing situation in university physics education in Taiwan was discussed in chapters 4 and 5 based on the students' and the lecturers' points of view, and a summary of the views of both groups is presented in chapter 6. According to an understanding of the existing situation and the literature, the researcher designed an intervention teaching program and implemented the program in this research. This chapter describes the design and implementation of this intervention program under six headings:

- (1) conditions of the teaching environment,
- (2) principles of the design of the intervention program,
- (3) design of the teaching content,
- (4) design of the teaching approach,
- (5) summary of the intervention design, and
- (6) implementation of the intervention.

7.1 Conditions of the teaching environment

The first step in the intervention teaching was to understand the teaching environment. This involved two main areas: (1) seeking agreement to implement the intervention program, and (2) restrictions and resources of the teaching environment.

7.1.1 Seeking agreement to implement the intervention program

Firstly, the researcher sought agreement in principle to implement the intervention teaching program from one of the physics lecturers (TL) and the director (YL) of the Physics Center at Feng-chia University.

The researcher presented a rudimentary description of the implementation of the intervention teaching to both TL and YL, which included:

- (1) the class: The researcher would select one of the classes with 3 lecture hours per week, which was assigned to TL, as the intervention teaching class.
- (2) the time/period: The intervention teaching program would commence at the beginning of the new academic year, in September 1998, and would take three weeks, nine teaching hours.
- (3) the topics: The topics of the program would be in the area of Classical Mechanics, and specifically limited to linear dynamics. The topic selection would follow the assigned unified syllabus.
- (4) the implementation: The researcher would teach the intervention program, and TL would be invited to observe the intervention teaching.
- (5) the design: The design of the intervention program was primarily aimed to improve the learning in physics knowledge, learners' motivation, and perceptions of learning university physics. The design would also comply with the administration policy, including the syllabus and the assessment.

The researcher's request immediately acquired agreement in principle as well as support, from both TL and YL.

7.1.2 Restrictions and resources of the teaching environment

Since the intervention teaching would be taught in a normal class, there were some restrictions imposed by the administration system and the teaching facilities, which needed to be considered in designing the program. These included:

- ***Unified syllabus and examination policy***

As explained in section 1.1 the unified syllabus and examination policy specifies what topics are to be taught each week, and the assigned syllabus determines the extent of the examinations. Thus, the lecturers need to cover the syllabus to enable the students to sit the examinations. The assigned syllabus is usually so heavy that there is limited flexibility for the lecturers to introduce alternative teaching materials and/or approaches, such as everyday life phenomena or group discussion. Certainly, this policy restricted the design of the intervention program to a certain extent.

Fortunately, three months before the implementation of the intervention teaching, the director, YL, informed the researcher that the unified policy had been dramatically modified during the syllabus meeting. The coverage of the assigned syllabus had been greatly reduced. Meanwhile, the percentage of the unified examination had been reduced from 100% to 50%. This meant that each lecturer was authorized to take responsibility for the other half of the examination design, to suit their own students with respect to what the lecturers had emphasized in their classes.

These modifications provided the lecturers, as well as the researcher, with more flexibility in teaching design. Owing to these modifications to the unified policy, there turned out to be little restriction to the intervention design, either in teaching content or in teaching approach.

- ***The class arrangement***

The class consisted of about 60 first year students all with the same major. The seating arrangement in class consisted of 8-9 rows by 8 lines of seats. This seating arrangement is excellent for traditional lecturing, since all of the students face the lecturer. However, this type of arrangement may retard the communication of peers, since the students do not see their peers' faces unless they turn their heads.

- ***Teaching facilities***

The teaching facilities available at Feng-chia were only a blackboard and an overhead projector (OHP). Therefore, to implement the intervention teaching, the

researcher was able to use transparencies, as well as to perform some simple demonstrations. Other teaching methods such as showing video programs, and performing demonstrations with a complicated setup were deemed to be impossible due to these limitations.

This section describes the limitations and resources of the teaching environment for implementing the intervention teaching. The next section will explain the fundamental principles of the intervention design.

7.2 Principles of the design of the intervention program

According to the understanding of the existing situation summarized in chapter 6, and referring to the education literature, several fundamental principles of the intervention program were developed and are discussed below. These principles also needed to consider the limitations and resources of the teaching environment. The two major principles of the intervention design were:

- (1) content design considering students' preferences, and
- (2) shifting the lecturer's role.

7.2.1 Content design considering students' preferences

The first principle was to adjust the content design to make it more in line with the students' preferences. From the students' responses, the major weaknesses in the content design of the existence physics course were that the course covers too much, and is too theoretical, irrelevant and repetitive. These opinions were mostly in accordance with the literature (eg, Amato, 1996; Tobias, 1989). Possible ways to make the content more meaningful to the students are discussed below.

The first way is to teach physics through phenomena, and to interpret the physics principles mainly by verbal description. This way of teaching physics is different from the traditional style, which is usually dominated by mathematical symbols and formulas to interpret the physics principles. It is expected that by making this adjustment, the physics principles become less abstract and more accessible to the

students (Tobias, 1989; Kalman and Kalman, 1996; Prentis, 1996).

Secondly, the intervention would introduce more life examples linking the theories to the students' experiences in order to eliminate the impression of the irrelevance and impracticality of the course (French, 1988; Hilborn, 1988; Ridgen, Holcomb and Di Stefano, 1993).

Thirdly, although the teaching has to cover the assigned topics, the heavy workload may still be adjusted by drastically reducing practicing problems in class. Solving problems usually includes complicated mathematical manipulation, and the students' complaints of too much mathematics have been shown to be highly linked to their perception of a heavy workload (see section 4.2.5). Therefore, a reduction in solving problems may greatly diminish the students' main concern about the fast teaching pace.

Finally, the structure of the teaching content needs to be adjusted so as to be different from that of the high school's, to avoid the impression of repetition. The content structure provided in the textbook needs to be modified to fulfill this task. More details concerning this issue are discussed in section 7.3.4.

In summary, the adjustment of the teaching content is aimed to eliminate students' negative feelings towards the course, and promote their learning motivations and outcomes.

7.2.2 Shifting the lecturer's role

The second principle in designing the intervention teaching was to shift the lecturers' role from information transmission to mediating learning. Although few concerns from either the students or the lecturers were found regarding the traditional didactic teaching style, the literature has highlighted the essentiality of lecturers being more aware of the students and their learning, in addition to teaching, in class.

In comparison with the traditional lecturers' role, three main tasks were set for the lecturer in the intervention teaching:

Firstly, lecturers need to provide the students with challenge when teaching

university physics, which includes providing novel questions and allowing students to discuss the possible answers/concepts, and intervening in students' alternative conceptions during the discussion process. In contrast to providing challenge, most of the lecturers put much effort into lowering the difficulty and challenge of the course for the reason of avoiding undermining the learners' confidence. However, from the students' responses, the lecturers' strategy of reducing challenge may have resulted in some unanticipated outcomes, such as feelings of boredom and repetition, and encouraging superficial learning (see section 6.3.3).

Providing more challenge to the students in the university physics course might have some advantages for the students, rather than undermining their learning confidence.

Firstly, lecturers can show that they have high expectations of their students by presenting them with different levels of challenge. Research has found that success in easy tasks is ineffective in enhancing learners' confidence (eg, Dweck, 1986), whereas if the students successfully meet the challenge by figuring out appropriate answers to a difficult or novel question, they are sure to feel a sense of achievement, and this achievement may enhance their own high expectations.

Secondly, challenging questions can help the students monitor their own learning outcomes. When the students do not succeed in answering the questions, they may not necessarily be overwhelmed by the challenge. Rather, the challenge may provide the students with a good opportunity to reflect on their learning outcomes and become aware of the weaknesses in their high school physics background. As discussed in section 6.3.1, many students might not realise that they did not understand the concepts completely when they criticised the content of university physics as being a repetition and/or boring. This strategy may help the students realise the reason why they need to learn similar topics again at university.

The strategy of increasing challenge in the university physics course can be more beneficial considering the Taiwanese students' sound physics background. Whether the challenge undermines the students' confidence or promotes awareness of the learning outcomes may depend on the learning environment, as

perceived by the students. When the learning environment is perceived to be friendly and supportive, the students are more likely to have a positive attitude towards their failure to meet the challenge. Therefore, the provision of a supportive learning environment needs to accompany the provision of a challenge.

The second task for the lecturer is to cultivate a supportive learning environment. The way to deliver the lecturers' support is for the lecturers to express their genuine concern for and awareness of the students' learning, including learning interest, learning progress and learning barriers in teaching, ie, to shift the focus of the class from teaching to learning. This is in contrast to the traditional didactic teaching, where little awareness is on learners. This teaching style can hardly allow the lecturers to acquire an understanding of the students' learning: how they learn, how they feel, and what they need, and thus makes it difficult to provide a supportive learning environment.

The third task for lecturers is to provide instant feedback to the students. When the students respond to the challenging questions, they expect feedback from their lecturer and/or their peers. Rennie and Punch (1991) noted that the instant feedback provided from the teachers to the students' achievements is helpful in promoting better learning attitudes, and results in better achievement thereafter. However, in traditional teaching, the lecturers may only receive their students' responses by giving tests and examinations. Even with respect to these limited student responses, many lecturers fail to provide quick feedback to the students.

To sum up, the lecturers need to shift their teaching role from purely devoting themselves to presenting information, to putting more attention and effort directly into the learners to facilitate, monitor, and intervene in their learning. Providing students with challenge in cognitive aspects, support in affective aspects, and instant feedback in both aspects are three major tasks for lecturers (Angelo, 1993; Scott, Asoko and Driver, 1991). More details about how the intervention teaching program performed these tasks are given in sections 7.3 and 7.4.

In addition to the emphasis that the lecturer places on the learners and their learning, it is also essential that the learners are engaged in the learning process. Therefore their responses must be incorporated into the whole learning equation.

7.3 Design of the teaching content

The design of the intervention program can be divided into two main parts: teaching content and teaching approach. This section describes the design of the teaching content. The four main features of the design of the teaching content in the intervention program are:

- (1) a reduction in problem-solving,
- (2) an emphasis on physics concepts and linking to life,
- (3) a concept test, and
- (4) concepts embedded by context.

7.3.1 A reduction in problem-solving

The first feature of the content design of the intervention program was a reduction in problem-solving.

In traditional university physics classes, problem-solving takes the majority of the teaching time. As discussed in chapter 5, many lecturers pointed out the expected advantages of practicing problem-solving, including helping the students to understand the concepts, equipping the students with the mathematical skills which will be required for their advanced study, and cultivating the students' thinking ability. However, what the lecturers expected from problem solving seemed not to be perceived/appreciated by the students. Meanwhile, the literature found that practicing problem solving does not necessarily lead to better understanding of physics concepts (eg, Heller, Keith and Anderson, 1992; Mazur 1996).

Meanwhile, from the students' responses, the perception of a heavy workload was strongly linked to too much mathematics (see section 4.2.5). Hence, the benefits of reducing the problem-solving may be that it also reduces the perceived workload, slows down the teaching pace, and diminishes the feelings of boredom when learning physics.

Furthermore, the task of problem-solving could be practiced out of class by the

students; it is not necessary for it to always be taught in the class. Based on the students' low agreement with the statement that their lack of mathematical skills is a major learning barrier (see section 4.5.3), it can be assumed that the students may have enough mathematical ability to solve the problems by themselves if they have a clear understanding of the physics concepts. Hence, reducing problem-solving while teaching can be supplemented by assigning the problems to the students to do out of class, and so will not necessarily result in sacrificing the enhancement of the learners' mathematical skills.

Reducing the teaching in problem-solving can provide valuable teaching time for some other teaching tasks, such as introducing life phenomena, and/or conducting group discussion. These tasks were found to be crucial to facilitating the students' understanding of physics concepts in the literature (eg, Gautreau and Novemsky, 1997). Emphasis on the physics concepts is also a feature of the intervention teaching, as discussed below.

7.3.2 An emphasis on physics concepts and linking to life

The second feature of the content design was the emphasis on physics concepts and linking to life. There is a consensus found from both the lecturers and the literature that developing students' understanding of physics concepts is a major aim of university physics courses. Hewitt (1994) claimed that

physics concepts are fundamental; the tools of physics and their application to solve problems are secondary. Mathematics is an essential tool for physics (p.224).

Research found that students could not solve the traditional problems mainly because of their deficiencies in understanding the concepts (Hestenes and Well, 1992). The above notions have raised the importance of clarifying concepts when teaching physics.

With respect to the lecturers' views, enhancing the students' understanding of the physics concepts was also regarded as a major goal of the course by most of the lecturers (see section 5.2.2). However, according to the lecturers' descriptions, their teaching usually started by interpreting the theory/concept verbatim, and was then followed by problem-solving thereafter. The goals of clarifying the physics

concepts are usually approached by these two steps, and there is a lack of utilisation of everyday life phenomena to interpret the concepts. This lack may be one of the reasons for the unsatisfactory achievement of the learners in understanding the physics concepts.

Meanwhile, the students criticised the course as being irrelevant to their everyday life. In addition, providing life examples has been shown to be significantly linked to learning interest (eg, Jones and Kirk, 1990).

Based on the above discussions, the content of the intervention teaching dramatically increased the teaching time spent on clarifying the physics concepts by introducing many phenomena and examples from everyday life. This type of information is usually seriously lacking in the calculus-based physics textbooks, and requires the researcher to search in other resources. References which provide good resources for information linking to everyday life, include Hewitt (1998), Walker (1977), Hobson (1982), Epstein (1983), Griffith (1997), Jewett (1996), Kirkpatrick and Wheeler (1995), and Butlin and Maybank (1996).

7.3.3 A concept test

The third feature of the content design of the intervention teaching was a concept test.

The constructivist research has identified the need for learners to be intellectually active in learning for conceptual development (eg, Osborne and Wittrock, 1985; Posner, Strike, Hewson and Gertzog, 1982). Meltzer and Manivannan (1996) noted that the major tasks of physics teachers are to provide good questions and promote student thinking. At the same time, a sociocultural view of learning addressed the crucial role of the students participating in social practice, such as group discussion, to share and negotiate the meanings of the physics concepts, be familiar with the tool usage, etc (eg, Bell and Gilbert, 1996; Driver *et al.*, 1994; Salomon and Perkins, 1998).

In the intervention class, the concept test was an important tool to stimulate the students to be intellectually active and engage their participation in group discussion. In each lesson, the researcher provided the students with 4-7

questions. These questions may be presented along with demonstrations, news reports, or legends, to enrich the context and link to real life.

The criteria for selecting the questions were (Heller and Hollabaugh, 1992):

- (1) The questions needed to be highly linked to everyday life;
- (2) To solve these questions required clear physics concepts, but no complicated calculations;
- (3) The known conditions were neither stated explicitly nor are well-structure, and
- (4) The context needed to be fresh for the students, to avoid recalling.

Cannon (1988) noted that

novelty is essential if the question is to stimulate high-level processes and not simply demand recall (p.39).

Good resources for concept questions which fulfill the above criteria include Walker (1977), Epstein (1983), Ehrlich (1988), Mazur (1996), and Hewitt (1998).

In traditional physics classes, the learning activities are limited to mainly listening to the lecturer and copying notes, and occasionally, watching lecturers' demonstrations. These activities often result in students being only passive receptors and fail to engage them participating in the learning process.

Meanwhile, in this research, it was found that most of the students did not actually comprehend the physics concepts well when they criticised the repetition between university and high school physics (see section 6.3.1). Concept tests can help the learners notice their weaknesses in understanding physics concepts. Concept tests may be particularly important for university students to promote their awareness of the incompleteness of constructing physics concepts and the need to study the university physics course.

7.3.4 Concepts embedded by context

The fourth feature of the content design was that the concepts and principles were embedded by the context.

The term “context structure” as used in this research means that one topic was chosen from everyday life phenomena for each teaching unit, and several physics principles linked to the topic were discussed within that unit. One physics principle may have appeared in more than one teaching unit. For example, in the car safety unit, the phenomena discussed included stopping distance, running or stopping on the yellow lights, car races etc. The physics principles covered in this unit included linear kinematics, Newton’s laws of motion, conservation of energy, and power. Newton’s laws of motion appeared again in the units on sports and satellites. A similar design was studied and reported by Di Stefano (1996) where a context called *Interplanetary Travel* was used to teach the whole subject of mechanics. The difference between the context structure in this intervention program and Di Stefano’s program was the scope, as the prior program adopted a narrower scope than the latter. The scope of the selected context is critical to the effectiveness of the teaching design, and a wider scope contains more topics and creates more difficulties for the teaching design in both matching the learners’ interest and covering the theories of the discipline (Di Stefano, 1997; Hipkins and Arcus, 1997).

The context structure of the intervention program was very different from the structure in conventional textbooks, and from most of the teaching in this course. The traditional teaching content and the textbooks are structured by discipline, i.e., each teaching unit is titled by a center-principle/theory. Each principle appears only once in the teaching, but the same phenomenon may appear again in different units, interpreted by different principles. The following figures illustrate the difference between the context structure and the traditional structure.

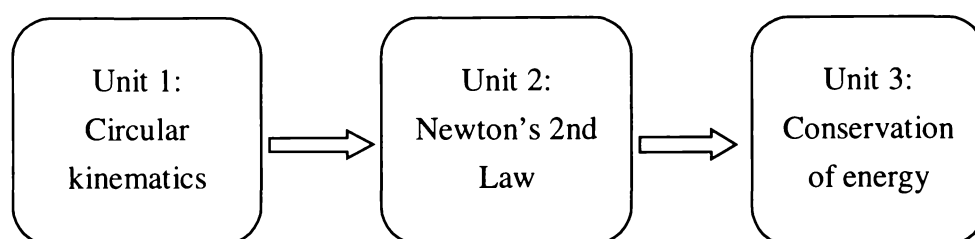


Figure 7.1 Traditional content structure where each theory appears once only

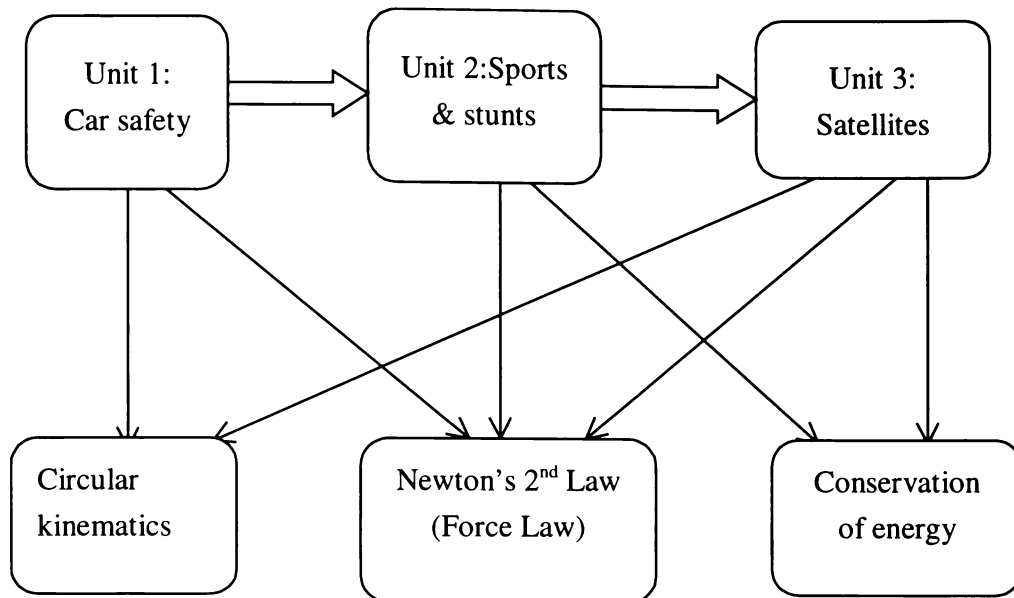


Figure 7.2 Context structure where each theory/principle appears in more than one unit

There were three main reasons for substituting the traditional structure with this context structure.

Firstly, the literature noted that context is essential for constructing concept, and the boundary of the given context determines the appropriation of the concepts (eg, Driver, 1989a; Linder, 1993a; Stinner, 1995). Meanwhile, the selected topics must be familiar to the learners. Students could not deal with the questions the context generates unless they already have some knowledge of the context (Stinner, 1995).

Secondly, the structure can help integrate several related physics concepts into a coherent picture. Since the context structure enables the students to learn different theories within one phenomenon, this allows the students to identify the links of related concepts. Having well integrated concepts is more powerful and valuable than having many discrete concepts. However, it was found that the existing teaching did very little in helping students to integrate concepts under the traditional content structure (see section 4.2.1), and the lecturers perceive this task as subsidiary to teaching this course (see section 5.4.4).

Lastly, context structure can provide more challenge to help the learners evaluate their understanding of what they learnt in high school. As discussed in section 7.2.2, the lecturers need to provide more opportunities to allow the university students to evaluate their existing understanding of the concepts, to promote awareness of the weaknesses in their high school background, and thus to realize the necessity of studying the topics again.

Gunstone and White's (1981) study found that the first year university students had a great deal of physics knowledge but were unskilled in seeing which bit applied to any given situation. Angelo (1993) claimed that many students could not recognize the concepts they had already learned if the context was shifted. Hence, providing different contexts for the same concept can help students evaluate their comprehension of existing concepts.

In the intervention program, the researcher showed the students that similar contexts could embed different theories, while the same theory can apply in very different contexts. One example of different theories to interpret similar context appears in unit 5. The speed of a swing spiral ball is inversely proportional to the rotational radius, based on the conservation of angular momentum principle, while a spiral cable car keeps constant speed motion due to the absence of tangential force. In unit 2, conservation of momentum applies in contexts which appear to be very different, eg, the collision of a bullet and block system, and the interaction of a swimmer and the pool.

Compared with the context structure, the structure of discipline is titled by the center- theory in each unit. Being informed of the title provides critical clues to the learners that can prevent them from searching and reflecting on their existing understanding of the concepts.

Although the context structure may have many advantages for the learners, as described above, this structure is very different from the textbook structure, and therefore the students may have difficulty coping with the mismatch of content structure between the teaching and the textbook. To diminish this mismatch, and to assist the students to revise the textbook out of class, a summary of the related theories along with their page numbers in the textbook were provided to the

students at the end of each lesson.

The intervention teaching content consisted of four units. Outlines of the content of each unit are listed in appendix D.

7.4 Design of the teaching approach

The second part of the intervention program design relates to the teaching approach. In comparison with the traditional teaching approach, there were three features of the intervention program:

- (1) interactive teaching,
- (2) questioning before teaching, and
- (3) life phenomena before theories.

7.4.1 Interactive teaching

The literature has highlighted the need for students to be cognitively active and to participate in social practices (eg, Bell B., 1993; Salomon and Perkins, 1998). Therefore, modifying the traditional didactic teaching to an interactive teaching approach is important in intervention teaching. To design an interactive teaching approach, the classroom activities in the intervention program included: (1) thinking about concept questions individually, (2) small group discussion, and (3) whole class discussion.

Reasons for these activities were: to activate cognitive engagement, to clarify understanding of physics concepts, to promote learning motivation, to share and negotiate peers' understanding of physics concepts, and to develop epistemological beliefs of what and how to learn physics (eg, Bell, 1999; Hammer, 1995a; Roth, McRobbie, Lucas and Boutonne, 1997; Salomon and Perkins, 1998).

However, to successfully implement an interactive teaching was also found to be very challenging as it requires a high learning motivation to facilitate. (see section

5.3.1) Several strategies may need to be beneficial to promote students' engagement in classroom activities.

Firstly, raising hands for the answers may overcome the prevalent problem of Chinese students feeling reluctant to air their opinions in public. The students may want to express their ideas quietly, but are reluctant to talk in public. Mazur (1996) suggested that the concept questions adopted in teaching should be in multiple choice form rather than open form in a large class. His suggestion was adopted for some questions in the intervention program. In the intervention teaching, the lecturer went through each alternative to allow the students to raise their hands for answers. This method can activate students' engagement and provide immediate feedback to their thinking, while avoiding the students' hesitation to speak in public.

Secondly, to stimulate the involvement in discussion, the selection of the concept questions is crucial, especially the degree of difficulty. The questions must not be too easy or the learners will feel bored, and they must not be too difficult or their confidence will be undermined. To be able to make a suitable selection, understanding the learners' background is essential.

Thirdly, to establish a close and friendly relationship among peers can also stimulate the students' willingness to join in the classroom activities. Learning motivation is not determined personally but highly linked to the classroom context; and hence providing a warm classroom atmosphere is critical to strengthening learning motivation (Fraser and Wubbels, 1995).

Fourthly, adopting teaching aids, such as demonstrations, may refresh the students during long lectures, warm up the classroom atmosphere, and promote the students' engagement in the class (Di Stefano, 1997). Due to the restrictions of the teaching facility, the intervention teaching merely introduced some transparencies and simple demonstrations.

The transparencies included (1) a diagram of the path of Voyager 1 and 2 (to explain gravity assistance for interplanetary journeys), (2) photographs of astronauts' facial distortion at launching (to illustrate the high acceleration

required for reaching escaping speed), (3) a copy of Newton's memorial British notes (to illustrate the contribution by Newton to physics and the mistake of the note design in the Newtonian planetary model), (4) a photograph of a person lying on a nail bed with a brick on his stomach, which is being hit with a sledgehammer etc. Transparencies can compensate to a certain degree for the unavailability of video facilities and the inability to set up complicated demonstrations.

Two demonstrations were introduced in the intervention teaching program. The first demonstration measured the weight difference of the hourglass with flowing sand and stable sand. The purpose of this demonstration was mainly to interpret the relationship between force and momentum change ($\vec{F} = \Delta\vec{p} / \Delta t$), and to clarify the distinction between weight and mass. The second demonstration was to observe the change of speed of a spiral-rotating ball. This demonstration was mainly to illustrate Newton's First Law. These demonstrations were followed by concept questions, which required the students to think individually, and to discuss with peers. Therefore, the demonstration became an important tool to initiate and to activate the interactive teaching approach.

Finally, to convince the students of the importance of and reasons for participating in discussion in physics class in the beginning, it may be necessary for the lecturers to explain the expected advantages of the interactive teaching method for the students, to trigger involvement (Banerjee, Vidyapati and Vidyapati, 1997; Cottle and Hart, 1996). In addition, the students must experience their own achievements, in order to maintain their engagement in the interactive teaching.

7.4.2 Questioning before teaching

The second feature of the teaching approach in the intervention program was questioning before teaching.

In the conventional university physics courses, if concept questions are provided, they usually appear after the related theory has been taught. This teaching approach of questioning after teaching may be regarded as reasonable for teaching high school physics, since the teaching material is novel to the high school students. However, this teaching approach may cause the university

students to feel that the content is repetitive, and even to feel bored, since the topics overlap with their high school physics (see section 4.2.1).

In the intervention teaching program, the lecturer firstly provided the students with one or two concept questions before interpreting the corresponding theory. Note that the questions before teaching approach needs to combine with the context structure to ensure that the lecturer does not disclose any clues about the respective principle to the students when challenging their thinking. If a lecturer teaches the linking theory, or even merely mentions the title of the principle prior to the questioning, she/he may destroy the function of the questioning. Students may easily obtain the solution without having the opportunity to examine their existing understanding of physics concepts.

In summary, the purposes of adopting the questioning before teaching approach are to provide stimulation for students to think, enhance awareness of their concept weaknesses, and avoid the impression of content repetition. This approach also needs to combine with the design of teaching content including concept test and context structure.

7.4.3 Life phenomena before theories

The third feature of the teaching approach in the intervention program was life phenomena before theories.

Traditional teaching of university physics usually starts with contextless statements of the theories and is then followed by problem solving. Phenomena in everyday life may appear at the end, but they are more often neglected.

In the intervention design, the teaching always started from phenomena that linked to students' everyday life experiences, and then gradually approached the corresponding physics concepts thereafter. Starting from life phenomena can make the students feel that physics is more relevant to the real world and more approachable (Dudley and Bold, 1996; Elton, 1997; French, 1998). Dudley and Bold (1996) called the phenomena before theory approach "top-down" teaching to distinguish it from the traditional teaching sequence. Jones (1988) found that when applications of science concepts are referred to only at the end of the lesson,

students tend not to remember the applications.

In the intervention program, the everyday life phenomena were presented in several different forms, including concept questions, demonstrations, news articles and legends. For example, in the unit on satellites, the teaching started with a news article about the launching of Taiwan's first satellite, and discussed the reasons for choosing the launching destination, and practical usage of the satellite. Then, it dealt with the related physics topics, including escape speed, rotating period and mechanical energy.

The phenomena before theory approach is consistent with the questions before teaching approach, where description of everyday life phenomena provides the context of the concept questions, and these questions are answered by teaching/interpreting the corresponding theory. This approach also needs to combine with the two features of content design: reduction of problem-solving and emphasis on physics concepts and linking to everyday life.

To summarise, the features of the teaching approach are all aimed to activate the learners' participation in the learning process in class. The lecturers' role has shifted from merely transmitting information to facilitating learning engagement, monitoring and intervening in learning outcomes.

A summary of the intervention design is presented in the next section.

7.5 Summary of the intervention design

According to the descriptions in the previous section, the intervention design includes seven features with respect to the two areas of teaching content and teaching approach. Many features complement each other, and share the same reasons and goals. These reasons/goals mainly follow the fundamental principles discussed in section 7.2.

This section summarises the design of the intervention program by linking the relations of the related features and the corresponding expected goals.

The links between the seven features of the design and the expected goals are illustrated in Figure 7.3, and are discussed in the following four steps.

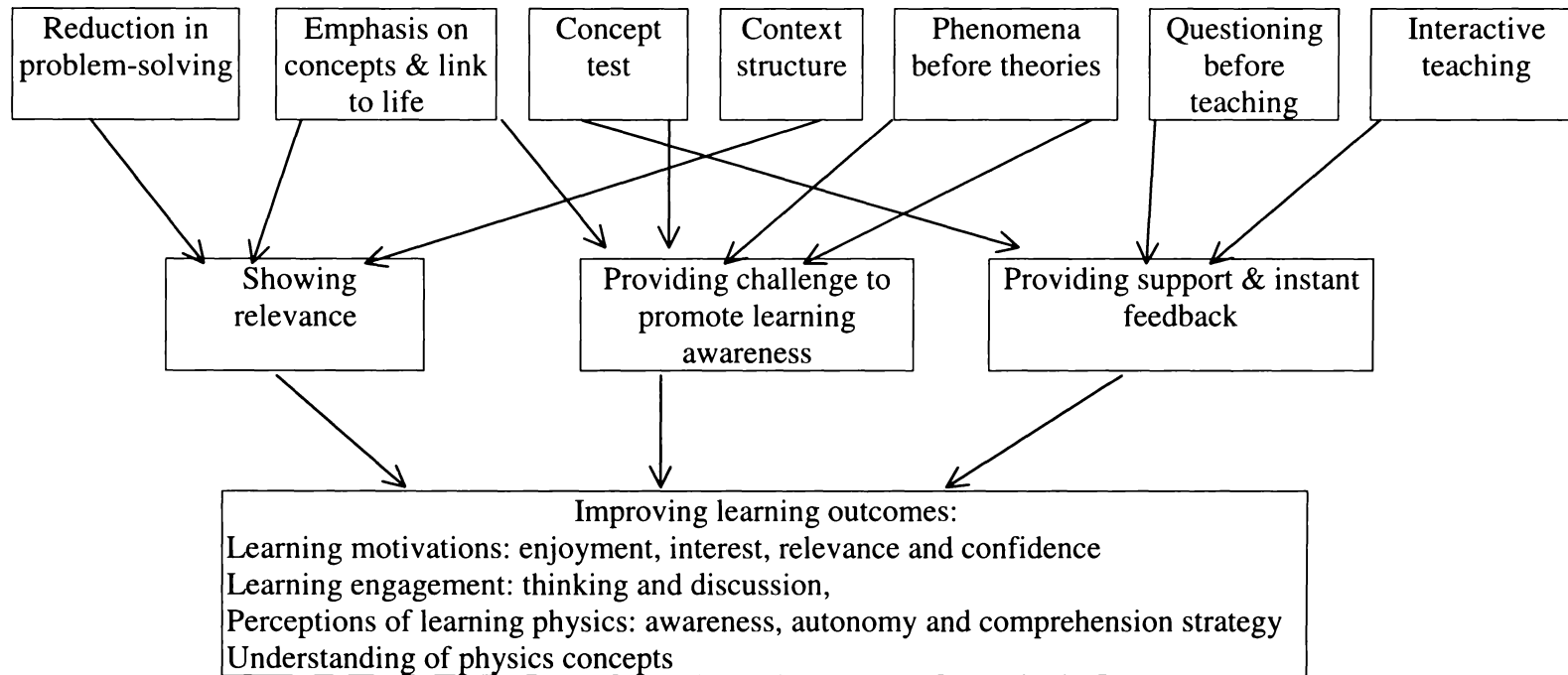


Figure 7.3 A summary of the intervention design

Firstly, three features of a reduction in problem-solving, emphasis on physics concepts and linking to life, and phenomena before theory are expected to be able to show the relevance of the course and promote learning interest.

Secondly, combinations of the four features in the content design of concept test and context structure, and the teaching approach of questions before teaching and phenomena before theory are expected to provide challenge to the students and therefore to promote their awareness of learning outcomes.

Thirdly, combinations of concept tests, interactive teaching and questioning before teaching are anticipated to provide support and instant feedback to the learners.

Finally, when the goals of showing relevance, promoting learning interest, promoting learning awareness, providing support and feedback are approached, the improvement in learning outcomes, including learning motivation, learning engagement, perceptions of learning physics, and understanding of physics concepts.

The next section describes the implementation of the intervention teaching program.

7.6 Implementation of the intervention

Two main processes of the implementation of the intervention program were: (1) communication with the lecturer, (2) explanation of the program to the intervention students, and (3) the implementation.

7.6.1 Communication with the lecturer

Before the researcher implemented the program, several communications with TL had been made to describe the details of the intervention design. The researcher briefly explained some pedagogical theories and the findings of the existing situation to TL to convince him of the reasons why the original teaching design needed to be modified. However, while the researcher persuaded TL that the intervention teaching design was aimed to improve the learning outcomes, the researcher also asked him to maintain his original teaching design, and traditional

format, when teaching his classes. Thus, a comparison could be made when evaluating the outcomes of the different teaching methods.

7.6.2 Explanation of the program to the students

At the beginning of the first lesson of the intervention teaching, the researcher gave a brief explanation to the students, in two parts: (1) the researcher's background and this research, and (2) major differences of the teaching design compared with traditional teaching.

The explanation focused on what the intervention program would encompass, and how it would be applied, but very little explanation was given to the students of why there would be differences in the teaching design from that of the traditional course. Since the intervention needed to be evaluated by the intervention students after program completion, to avoid possible bias in the evaluation due to the researcher's "persuasion", the researcher deliberately skipped the explanation of the reasons for the design. Details of the explanations to the intervention students during the first lesson are listed below.

(A) The researcher and the research:

- (1) The researcher has been a physics lecturer at Feng-chia University for 12 years and is now working on her doctoral thesis in New Zealand. The topic of the thesis is Improving Teaching and Learning of University Physics in Taiwan.
- (2) The first half of the research, which was to understand the existing situation based on both the students' and the lecturers' points of view, was completed. The second half of the research was to implement a new teaching design and to evaluate the outcomes compared with the traditional teaching.
- (3) The implementation of the intervention teaching program would be conducted by the researcher for three weeks, and then TL would pick up the teaching after the program.
- (4) During the implementation period, some intervention students would be invited to be interviewed by the researcher to make comments about the

program. These interviewees would be recruited on a volunteer basis. The students' responses would be referred to in order to modify the following intervention teaching.

(B) Features of the intervention teaching:

(1) What will the lecturer do for you?

- Content: (a) Focus on concepts and illustrate with everyday life examples.
(b) Structure by context.
(c) Provide questions to clarify your understanding of the concepts.
- Approach: (a) Promote interaction in class.
(b) Evaluate and monitor your learning constantly by concept tests.

(2) What will the lecturer not do for you?

- Follow the structure of the textbook, which is similar to the high school physics textbook.
- Teach everything in the textbook.
- Practice much problem-solving in class. This would mostly be assigned to the students to do in their own time.

(3) What does the lecturer expect you to do?

- Be intellectually active.
- Actively join the discussions, express your thinking/concepts in class.
- Complete assignments out of class.
- Be curious, creative and ready for the challenge.

7.6.3 The implementation

During the nine hours of intervention teaching, TL observed the researcher's

teaching, and wrote his comments on the program. Also, the researcher and TL discussed his comments and suggestions briefly after each intervention unit.

The responses from TL and the intervention students (in the interviews) provided the researcher with some suggestions for modifying the program. Based on their suggestions, the researcher made a slight modification to the following teaching units, mainly to reduce the content and teaching pace, and, as a result, the intervention teaching omitted the last unit (unit 5).

The intervention program contributed to some degree to the students' assessment. The students' responses to the concept questions provided in class were not counted into their grades. However, their answers to the assigned problems were marked by the researcher and contributed to a minor proportion of their final grades. During the intervention teaching, the researcher did not give the students any quizzes to assess their achievement. However, after the program was completed, the researcher designed 15 questions based on the materials of the intervention teaching to become part of the examination questions. This policy had been announced to the students to ensure that the intervention teaching was linked to their assessment.

This chapter has described the design and implementation of the intervention teaching program. The outcomes of this program were evaluated and will be discussed in the next two chapters.

Chapter 8

Evaluating the intervention teaching (Part I): A quantitative analysis

To evaluate the outcome of the intervention teaching, both quantitative and qualitative methods were used. The quantitative analysis will be discussed in this chapter, and the qualitative investigation will be described in the next chapter.

In this chapter, the quantitative evaluation includes two main research activities: academic performance tests and survey 3B, which consisted of closed and open-ended questions. The outcomes of the intervention teaching program will be discussed under four heading:

- (1) results of the closed questions,
- (2) responses to the open-ended questions,
- (3) further discussion of the outcomes of the intervention program, and
- (4) summary of the findings of the intervention teaching program.

8.1 Results of the closed questions

The first step in quantitatively evaluating the intervention teaching program is mainly based on the students' responses to the closed questions in survey 3B, which included the intervention class and seven traditional classes. The questionnaire design of survey 3B is described in section 3.4.1.

To evaluate the outcomes of the intervention teaching, compared with the traditional teaching, the results were analysed in three ways: (1) dis/agreement percentages, (2) t-test, and (3) rank of the intervention class amongst all 8 classes, with respect to each question. The agreement percentages of both the intervention (IT) and the traditional (TD) classes are listed, where disagreement percentages are indicated by shaded areas. A t-test of the scores referring to their agreement

was utilised to evaluate the significance of the intervention class responses compared with the responses of the traditional classes.

The closed questions can be grouped by their center-issues and discussed in four parts as follows:

- (1) the teaching content,
- (2) the teaching approach,
- (3) the course overall, and
- (4) the learning.

8.1.1 The teaching content

The first issue of the students' evaluation of the intervention program is respect to the teaching content. There were four questions related to this issue, and the results are listed in Table 8.1.

Table 8.1 Students' evaluation of teaching content

Questions	Dis/agree % IT (TD)	t-test	Rank order of intervention class (N=8)
The teaching content in my physics class can induce my <u>interest</u> in learning	66(36)	$p < 0.001$	1
My physics lecturer has provided plenty of reference information linked to <u>everyday life</u> in his/her teaching content	96(53)	$p < 0.001$	1
My physics lecturer has clarified clearly the <u>key points</u> of his/her teaching materials	72(74)	n.s. at $p = 0.1$	5
I have only learnt <u>discrete</u> pieces of <u>knowledge</u> , not integrated concepts	58(56)	n.s. at $p = 0.1$	5

Note: Shaded areas indicate the disagree percentages as the question is negative.

As shown in Table 8.1, the intervention students gave significantly positive responses to the questions about the content design inducing learning interest and linking physics to everyday life. The agreement percentages in the intervention class were as high as 96% with respect to the item of linking physics to everyday

life, and 66% with respect to the item of inducing learning interest. The agreement percentages of these two items were much higher than those of the traditional classes, and the results of the t-test for these two items were both significant at $p < 0.001$ level. Meanwhile, with respect to these two items, the average scores of the intervention class were ranked top amongst all eight classes. The above results indicate the intervention students' strong agreement that the teaching content linked physics to life and induced learning interest, which matched with the original design of the intervention program (see section 7.2.1).

However, for the tasks of clarifying the key points, and integrating the concepts to avoid feelings of discrete pieces, the intervention teaching was evaluated as being similar to the traditional teaching. The dis/agreement percentages of these two groups appeared to be consistent, and the t-test was non-significant at the $p = 0.1$ level. According to the above results, it appears that most of the intervention students were unable to appreciate the context structure of the intervention program which aimed to integrate the concepts better than the traditional structure. Meanwhile, the context structure may retard the clarification of the key points. The context structure may have resulted in the students' concerns about the mismatch between the teaching and the textbook structures. Furthermore, in order to stimulate the students' thinking, the researcher deliberately withheld the corresponding theory/concept when describing the phenomena, i.e., the phenomena before theories approach. This teaching approach may have prevented the students from realising that the teaching content was well structured.

As mentioned in section 7.3.4, the design of the context structure was expected to result in some important achievements, such as integrating the related concepts, providing more challenge, and facilitating cognition. This new structure, however, might not be accepted so easily by the students because they are more used to the traditional structure. The implementation of this structure design may require some modifications, and it may take time for the students to adjust their learning habits and gradually become used to it. Perhaps only then will the expected goals be achieved. More details based on the intervention student interviews will be discussed in section 9.1.2.

8.1.2 The teaching approach

The second issue of the students' evaluation of the intervention program is related to the teaching approach. There were four questions related to this issue, the results of which are listed in Table 8.2.

Table 8.2 Students' evaluation of teaching approach

Questions	Dis/agree % IT (TD)	t-test	Rank order of intervention class (N=8)
My physics lecturer has adopted a <u>one directional delivery</u> teaching method	81(43)	$p < 0.001$	1
In the physics class, the teaching methods are <u>monotonous</u>	81(37)	$p < 0.001$	1
My physics lecturer has been <u>aware</u> of our <u>learning outcomes</u> when teaching	77(60)	$p < 0.001$	2
In the physics class, I am involved in the <u>discussions</u>	81(32)	$p < 0.001$	1

Note: Shaded areas indicate the disagree percentages as the questions are negative.

According to Table 8.2, the intervention students made significantly positive comments in all items about the intervention teaching approach. Over 80% of the intervention students disagreed that the teaching was monotonous and limited to one directional delivery, while in the traditional teaching classes, the disagreement percentages were only about 40%. The intervention teaching lecturer (the researcher) was also shown to be more aware of the learning outcomes than the traditional teaching lecturers. Meanwhile, as many as 81% of the intervention students agreed that they were involved in the discussion in class, in contrast to only 32% agreement in the traditional classes. With respect to these four questions, the intervention teaching class was ranked in the top two of all the eight classes. From the t-test statistics for these four questions, the scores of the intervention class were also significant, at $p < 0.001$, compared with the traditional classes.

According to the students' responses, the teaching approach of the intervention design seemed to have successfully facilitated student participation in class activity, avoided feelings of boredom, and shifted the focus of the class from the

teaching to the learning. The students' responses matched the aims of the intervention design (see section 7.2.2). More details of the responses with respect to the new teaching approach in the open-ended questions and the student interviews will be discussed in sections 8.2.3 and 9.2 respectively.

8.1.3 The course overall

The third issue of the students' evaluation of the intervention program is related to the course overall. There were seven questions related to this issue, of which the results are listed in Table 8.3.

Table 8.3 Students' overall evaluation of the course

Questions	agree % IT (TD)	t-test	Rank order of intervention class (N=8)
The physics lessons promote my <u>interest</u> in learning physics	58(40)	$p < 0.01$	1
I feel <u>satisfied</u> with the physics course overall	74(55)	$p < 0.01$	2
The physics lessons reinforce my <u>confidence</u>	43(28)	$p < 0.05$	2
The physics lessons develop my <u>thinking</u> ability	81(66)	$p < 0.05$	2
In the physics class, I feel that learning physics is a matter of <u>enjoyment</u>	55(47)	$p < 0.05$	3
I have very good learning <u>achievements</u> from the physics lesson	66(54)	$p < 0.05$	4
The physics lessons enhance my physics <u>concepts</u>	75(72)	n.s. at $p < 0.1$	5

With respect to the students' overall evaluations of the course, as shown in Table 8.3, the intervention students gave a positive appraisal for most of the items of the course overall. The intervention class was ranked in the top two of the eight classes in the areas of promoting interest in learning physics, feelings of satisfaction, reinforcing confidence in their ability, and developing in thinking ability. For the feeling of enjoyment, the intervention class was ranked third amongst all of the classes, which is less significant than the feelings of interest and satisfaction. In Mandarin, enjoyment implies easiness and relaxation. Since the intervention design aimed to create more cognitive challenge to the students,

this may explain why the outcome of feeling enjoyment comparatively less significant than the other affective outcomes. The results of the t-test between the intervention class and the traditional ones, with respect to the above five items, were significant at the level of $p < 0.05$. The students' responses matched the researcher's original expectations when designing the program, which aimed to promote the affective learning outcomes.

The positive responses from the intervention students with respect to the above five items may be the result of their agreement with the content selection and the teaching approach design in general.

However, the outcomes of the intervention teaching with respect to the last two questions listed in Table 8.3 were not significant. The responses to the perceptions of their learning achievements and enhancing physics concepts placed the intervention class in the middle of the eight classes. According to the correlation coefficients, these two terms were highly linked ($r = 0.63$). The so-called learning achievement perceived by the students might be mainly limited to their achievements in the area of subject knowledge rather than in a wider field, included developing thinking ability, learning attitudes, and perceptions of learning physics.

In addition to the survey, academic tests were also distributed to the two groups to evaluate their academic achievements. The results of these tests are discussed in section 8.3.1.

The next section will discuss the students' self-evaluation of their learning.

8.1.4 The learning

The last issue of the students' evaluation of the intervention program is related to their own learning. There were seven closed questions and one open-ended question related to this issue. Results from both types of questions will be discussed separately.

The results of the closed questions are listed in Table 8.4.

Table 8.4 Students' evaluation of their own learning

Questions	Dis/agree% IT (TD)	t-test	Rank order of intervention class (N=8)
I concentrate on <u>listening</u> to the lecture in the physics class	79(69)	$p < 0.05$	2
If my lecturer <u>won't</u> record the attendance, I will <u>not</u> attend the physics class	92(75)	$p < 0.01$	1
In the physics lessons, I am engaged in active <u>thinking</u>	83(65)	$p < 0.001$	1
I develop a more flexible and <u>deeper learning</u> strategy from the university physics lessons	55(21)	$p < 0.001$	1
Till now, I have learnt <u>nothing</u> from this course	91(78)	$p < 0.01$	1
I am not interested in physics at all; I just expect to pass the course with <u>minimum effort</u>	68(63)	n.s. at $p = 0.1$	3
I regard an <u>interactive</u> teaching method as more <u>effective</u> in helping learning, than one way delivery	91(84)	n.s. at $p = 0.1$	3

Note: Shaded areas indicate the disagree percentages as the questions are negative.

Along with the positive responses to most of the questions about the course overall, the intervention students also gave positive responses when evaluating their own learning. Amongst all the classes, the intervention class students expressed the strongest agreement with willingness to attend the class, engagement in thinking in class, and development of a deeper learning strategy. They also expressed the strongest objection to learning nothing from the course. The results of the t-test between the intervention class and the traditional classes for these four questions were significant at the level of $p < 0.01$. Meanwhile, the intervention teaching also received more positive responses from the students in the area of concentrating on listening to the lecture, for which it was ranked second amongst all of the classes.

The results indicated that the intervention program had successfully promoted learning attitudes, learning engagement, and the adoption of learning strategy.

However, although the intervention students expressed stronger objection to the

passive approach of minimum effort to pass, and more expectations of adopting an interactive teaching method, the differences between the two groups for these two questions were non-significant, according to the t-test. These two items were mainly determined by the students' perceptions of learning, which may have been influenced by their previous experiences in learning physics in secondary school. The influence of the current teaching style may take longer to manifest itself.

In addition, the researcher also investigated the students' learning commitments out-of-class. In survey 3A, the incoming students were asked to estimate their expectations of how many hours per week they would spend studying for the course. Three weeks after the intervention program, in survey 3B, the students were asked to evaluate their actual study hours.

The percentage distributions of the expectations of the two different groups are illustrated in Figure 8.1 and Table 8.5.

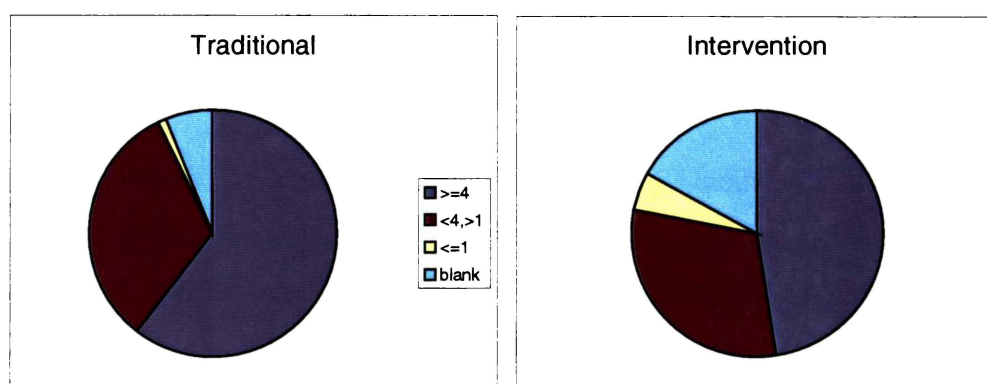


Figure 8.1 Original expectations of out of class study hours for physics

Table 8.5 Original expectations of study hours

	>,= 4 hr/wk	<4, >1 hr/wk	<,= 1hr/wk
Intervention	47%	31%	5%
Traditional	61%	33%	1%
All students	57%	32%	2%

According to the results shown in Table 8.5, the students' original expectations were quite consistent between the traditional and the intervention groups, with the intervention students' expectations slightly lower than those of the traditional

group. Most of the incoming students had high original self-expectations, which were in accordance with the findings of this research in survey 1F (see section 4.5.1). Over one half (57%) of the incoming students expected that they would spend at least 4 hr/wk (hours per week) studying physics out of class, and only 2% of the students intended to spend 1 hr/wk or less studying for the course.

However, after three weeks of study, as reported in survey 3B, most of the traditional students' study efforts appeared to be significantly lower than their original expectations. A comparison between their original expectations and the actual implementation is presented in Table 8.6, which shows that the traditional students' high original self-expectations were not actually realized.

Table 8.6 A comparison between original expectations and actual implementation for the traditional group

	>= 4 hr/wk	<4, >1 hr/wk	<= 1hr/wk
Expectation	61%	33%	1%
Implementation	21%	39%	37%

In contrast to the students in the traditional class, the students in the intervention group largely realised their original expectations, and in fact a considerable number of students actually surpassed their original expectations spending more time studying physics than they had originally planned! A comparison between the expectations and the actual implementation is made in Table 8.7.

Table 8.7 A comparison between original expectations and actual implementation for the intervention students

	>= 4 hr/wk	<4, >1 hr/wk	<= 1hr/wk
Expectation	47%	31%	5%
Implementation	42%	49%	2%

A comparison of the two groups in actual implementation of study hours is presented in Figure 8.2. This figure makes it clear that the hours spent studying physics by the two groups of students were widely divergent. The intervention students demonstrated a much higher learning commitment than the traditional

group.

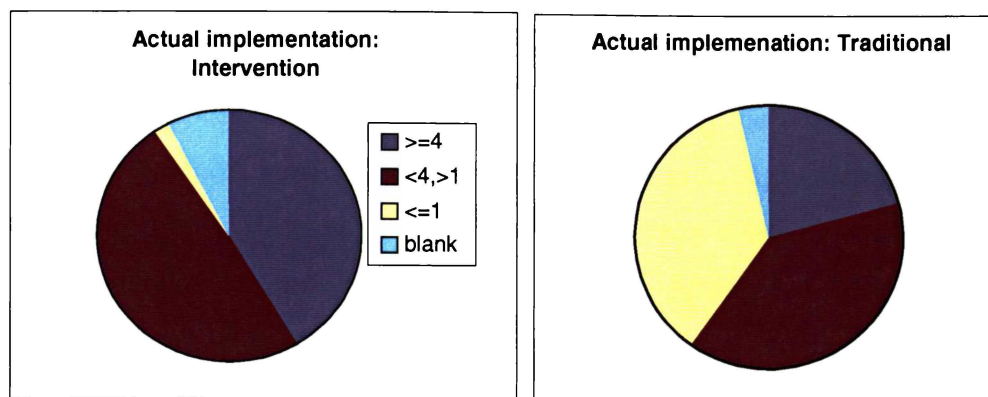


Figure 8.2 Actual implementation of out of class study hours for physics

According to Figure 8.2, over 40% of the intervention students reported that they had spent at least 4 hr/wk studying physics, while only half that percentage (21%) of the traditional students fulfilled this goal. At the lower level, less than 2% of the intervention students admitted that they had studied physics for no more than 1hr/wk, in contrast to as high as 37% of the traditional group.

The intervention teaching design intentionally created more challenge to the students in cognitive aspects, which may have promoted the students' awareness of the need for studying physics, and thus increased their learning commitment. On the other hand, many of the traditional students may have maintained passive study habits, which meant that they would not study except for a coming quiz or examination. Since the survey was made in the fourth week, many lecturers may not have given any quizzes yet, and thus many of the dependent students may not have realized the need for study.

Although the intervention teaching had not given any quizzes either, the intervention students seem to have taken some responsibility for their own learning. Therefore, the study hours implies that the intervention teaching may have encouraged the students to become more autonomous in contrast to the passive and dependent learning attitude possessed by the traditional students.

Further investigation of the two groups was made with the analysis of the responses to the open-ended questions, which are discussed in the next section.

In summary, the intervention teaching received significantly more positive

appraisal from the students in most areas. When compared with the traditional teaching, the intervention program seemed to achieve better affective learning outcomes, including feelings of interest, enjoyment and satisfaction. Meanwhile, the program appeared to successfully facilitate learning motivation and learning engagement in class, including willingness of attendance, engagement in thinking, and participation in discussion. The students' learning commitment out of class was also found to be much higher in the intervention group than in the traditional. Moreover, the program was found to be beneficial to enhance learning confidence and promote the adopted learning strategies. These achievements are in accordance with the researcher's original expectations when designing the program.

However, the modification of the context structure in the intervention teaching (see section 7.3.4) seemed not to be appreciated by the students in its original aims of facilitating cognition and integrating concepts.

8.2 Responses to the open-ended questions

The second step of the analysis of students' evaluation of the intervention program is to discuss their responses to the open-ended questions in survey 3B. In survey 3B, two open-ended questions followed the closed questions. These two questions asked the students to point out one or two strengths and weaknesses of the course, and to give reasons for their comments. Since the responses of the intervention students and the traditional students appear to have a different focus, in order to clarify the students' comments, the results of the two groups will be firstly discussed separately, and then compared later. The results are discussed under four headings:

- (1) results of the traditional classes,
- (2) results of the intervention class,
- (3) comparison of the intervention and the traditional teaching, and
- (4) comparison of the traditional teaching in two consecutive years.

8.2.1 Responses of the traditional classes

The first step in discussing the students' responses to the open-ended questions is to present the results of the traditional classes. The results were analyzed by grouping similar statements together as one item, and counting the total responses for each item. The method of analysis and discussions was similar to that applied in survey 2 (see section 4.3).

The most significant comments made by the students of the traditional classes are listed in the following Table 8.8.

Table 8.8 Responses of the traditional classes to survey 3B

Statements	Responding frequency
• Teaching pace is too fast	23
• Teaching content is repetitive	9
• Feeling interested (bored)	54 (51)
• English barriers (provide assistance)	17(5)
• Introducing (lacking of) life examples	35 (16)
• Clarifying concepts (too much math)	20 (13)
• Adopting interactive (didactic) teaching	12 (14)
• Promoting (lack of) thinking	9 (13)
• Lucid (inarticulate) lecturing	33 (5)
• Systematic (non-systematic) structure	19 (15)
• Working hard on teaching	8

Note: Total student number was 327

According to Table 8.8, opposing comments were expressed by the students for many statements. Some statements may also be related to others. These statements are discussed below accompanied by their quotes, in the order of their appearance in the table.

Firstly, 23 students felt that the teaching pace was too fast, and no opposing comments were made. In accordance with previous findings in phase 2 (see section 4.3.1), this problem was still a major concern for the students. For example,

The lecturing speed is too fast which makes it hard for me to understand and to follow.

The professor teaches too fast, and so there is no time for us to think.

The teaching pace is too fast, and copying notes prevents us from listening.

Keeping copying notes throughout the whole lesson makes me feel really tired.

According to the above quotes, the fast teaching pace seems to have retarded the cognitive processing as well as deteriorated learning motivation. Also, according to the responses, many students seemed to limit their learning task to merely listening to the lecture and copying notes. Only a few students pointed out the task of engagement in thinking, and no comments were found concerning the lack of social practice in the physics classroom, such as group discussion. This implies that the students may regard the role of themselves as learners as passive receptors rather than as active participants in the physics class.

The second concern of the traditional students was that 9 students felt that the content was too much of a repetition of their high school physics. For example,

I dislike the fact that the professor always keeps teaching the same old content. The repetition makes me feel bored.

The course is just a repetition of what we have learnt, but modified into an English format.

The course is just a repetition of our high school physics, nothing new, and the professor's teaching is even worse than our high school teacher's.

The above quotes indicate the students' concern with the content repetition, as well as their lack of awareness of the need for developing their understanding at the physics concepts, which had been taught in high school.

The third concern found in the traditional group was that there were about an equal amount of positive and negative responses to the questions related to learning interest. There were 54 students who responded that they felt interested in the course, compared with 51 who admitted to feeling bored. For example,

The professor's tone was too flat, his classes lacked life examples and make it easy for me to fall asleep.

The content is too dull, since it fails to attract my attention, and reduces my learning interest and thinking.

The classroom atmosphere is cold; this makes the students absent-minded and sleepy.

The professor talking all the time makes me doze.

The professor is humorous, and so makes the lesson very interesting.

The classroom atmosphere is vivid since the professor is humorous.

About one third of the students (105 out of 327) gave responses concerning this affective dimension. Since the students mostly made only one or two points about their perceptions of the course in the open-ended questions, their high concerns with learning interest revealed the importance of this affective consideration in teaching design. This result supports the principle of the intervention design emphasising affective learning outcomes (see section 7.2.1).

Although the responses regarding feelings of interest and boredom seem to be balanced overall, the distributions of the classes were quite diverse. The responses of feeling interested mostly came from the same class (class P), from which 39 students noted that the teaching was appealing and interesting, and only 6 gave opposing comments. If this class is taken out of the equation, the total results of the other six classes become 46 responses of feeling bored, in contrast to only 15 responses of feeling interested. Feelings of boredom therefore still seem to be prevalent in most of the traditional classes, also consistent with the previous findings (see section 4.3.1). According to the above quotes, the reasons for feeling bored include content selection and the didactic teaching approach which lacks interaction.

The fourth concern of the traditional group was that 17 students noted the barriers of the use of English either when reading the textbook and/or when trying to understand the teaching terminology. Only 5 students noted that their lecturers had provided assistance in the understanding of the English used. For example,

All the material is in English. This is very difficult for me to understand, and I need help to translate the content.

The professor gives Chinese explanations when he writes the English terms,

so I don't need to spend much time checking the dictionary.

Since four out of the five students who commented on their lecturer's help with English were in the same class, it is implied that most of the lecturers do not provide enough support to their students to overcome this learning barrier.

The fifth issue of the traditional group was that more positive comments than negative were made concerning the content selection. 35 students regarded the main strength of the course as the fact that their lecturers had provided everyday life examples, and 16 students criticized the course for the fact that there was a lack of life examples. For example,

The professor introduces life examples to help reinforce my memorization of the concepts.

I like the professor to introduce life examples, since this can link the theory to practical usage, and retain the knowledge in my mind.

Our professor often introduces life examples to us. This can avoid monotony and it promotes our interest.

The content is too theoretical and so makes me feel bored.

According to the above quotes, the advantages of introducing life examples include promoting learning interest and benefiting cognitive outcomes. The responses also indicate that many students regard learning physics as a process of memorizing rather than understanding the concepts.

Meanwhile, 20 students noted that their lecturer had put emphasis on clarifying the physics concepts, in contrast to 13 students who noted that the teaching devoted too much time to mathematics. For example,

I like the fact that the teaching emphasis is on clarifying the concepts and teaching only the key points, since I really need this kind of help from my teacher.

The course helps to me have a better understanding of the concepts I was unclear about in high school.

The monotonous mathematical derivation makes me feel that the lesson is very boring.

Tedious and complicated mathematical calculations make my mind dizzy.

Many students expressed a need for clarifying concepts, while very few felt a need for practicing their mathematical skills. These responses supported the intervention design dramatically reducing the mathematics and instead emphasised clarification of the concepts (see sections 7.3.1 and 7.3.2).

The sixth concern of the traditional group was in the area of teaching approach and learning engagement. The positive and negative responses were fairly balanced. Twelve students noted that their lecturers had adopted interactive teaching, and 14 criticised the lack of interaction. Nine pointed out that the teaching had promoted their engagement in thinking, while 13 students perceived that the teaching failed to induce their intellectual engagement. For example,

I like the interactive teaching method, since this can stimulate and promote my thinking ability.

The professor introduces an interactive way of teaching, which can help our thinking and clarify our understanding of the concepts.

I like the interactive way of learning, since the professor will notice our learning outcomes.

The teaching continues to be "force-feeding", just like at high school. This is what I always dislike.

I dislike the one directional teaching, which diminishes (my) learning motivation.

The students' responses show that the advantages of adopting an interactive teaching approach included promoting learners' engagement in thinking, enhancing understanding of concepts, and enabling the lecturer to understand the students' learning outcomes. The link between interactive teaching and promoting thinking particularly apparent, as these two strengths were mostly mentioned together. Meanwhile, responses concerning these two strengths mostly came from two classes. Nine out of the 12 responses were evenly distributed between these two classes with respect to the two strengths, and no negative comments were made by these students. When these two classes are excluded, the other five classes seem to have been restricted to the didactic way of teaching, and to have failed to engage the students intellectually.

These two classes which received praise from the students for promoting

interaction were taught by TL and YL. As mentioned in section 7.1.1, the researcher had spent many hours communicating with them and explaining the reasons for and details of the intervention design, when seeking their permission to implement the program. This communication procedure was more of a “conversation”, exchanging opinions about teaching modifications, rather than instruction. The researcher suspects that the communication procedure contributed to an adjustment in her colleagues’ teaching approach which shifted from a didactic approach to a more interactive way of teaching. Details of the change of TL and YL’s students’ comments over the two years before and after the communication will be discussed in section 8.3.6.

With respect to other comments from all traditional students, the number who mentioned the didactic way of teaching appeared to be low. This result implies that most of the students may not be critical of the didactic teaching approach. This result is consistent with the findings in phases 1 and 2, and is summarised in section 6.1.3.

The last comment responded by the traditional groups was that the students tended to positively evaluate their lecturers’ performance. Thirty- three students noted that their lecturers had presented lucid lectures in contrast to five opposing comments. For example,

I like the professor’s teaching performance. He can explain the concepts clearly and helps us to clarify the key points.

The professor has interpreted the concepts clearly, but the tone is too flat to retain my attention.

Meanwhile, 19 students commented that the teaching material was systematic while 12 students gave an opposing response. For example,

The teaching content is not systematic and makes it hard for us to grasp the key points.

The professor sorts out the key points for us and thus makes our learning more efficient.

I dislike the fact that the professor doesn't clarify the key points, since to pick up the key points is the main reason for us to attend the class.

Furthermore, 8 students praised their lecturers for working hard on teaching, and no opposing opinions were found. For example,

I feel that our professor works hard on teaching; many classmates appreciate his teaching commitment.

I like the professor's attitude; he teaches very hard. However, I do not absorb the content well since I feel tired.

These three strengths of lucid lecturers, systematic structure and teaching commitment appeared to be fairly consistent across most of the classes. Therefore, most of the students seemed to be satisfied with the teaching performance and commitment. However, according to the students' responses, this teaching commitment and performance seemed not to benefit the students' learning outcomes.

The above discussions are from the traditional students' responses, and the intervention students' responses are detailed in the next section.

8.2.2 Responses of the intervention class

The second step in the discussion of the students' responses to the open-ended questions is the analysis of the responses of the intervention class. These responses are listed in Table 8.9.

Table 8.9 Responses of the intervention class to survey 3B

Statements	Responding frequency
• Introduces life examples	26
• Clarifies concepts	8
• Lack of discussion of the assigned problems	6
• Too difficult	5
• Systematic (non-systematic) structure	6(4)
• Promotes learning interest/curiosity	13
• Adopts interactive teaching	22
• Stimulates thinking	12
• Achieves a better outcome	10

Note: Total student number was 53.

According to Table 8.9, the intervention students' comments can be analyzed as follows.

Firstly, introduction of everyday life examples received strong agreement from the students. As many as 26 out of the 53 intervention students noted this strength, and most of them also stated the advantages of introducing life examples. For example,

I like the satellite unit, the teaching has made the cold theories full of life. Thus, we can learn the practical usage of physics theory.

The class often starts from the phenomena surrounding us, and these can promote my curiosity and stimulate my thinking.

Amongst the 26 responding students, 7 students noted that life examples promoted their learning interest and/or curiosity; 6 students stated that life examples made the course more practical. Meanwhile, 8 students claimed that the course had enhanced their understanding of physics concepts, and all of the responding students linked this achievement to the introduction of life examples. For example,

The lecturer does not only teach theory but also utilizes life examples to interpret the theory. This makes it easier to understand the concepts.

The students' responses pointed out the advantages, in both the affective and cognitive aspects, of introducing life examples.

The second issue raised by the intervention students was the feeling of difficulty with respect to the new teaching design. Six students were concerned about the absence of solutions to the assigned problems. For example,

The lecturer should show us the correct solutions to the assigned problems (after we hand them in).

No solutions were provided after we handed in our assigned problems, thus we were unable to know the correct solutions.

Although the students noted their request to the lecturer to provide the solutions to the assigned problem, no one argued against the reduction of problem solving in the intervention teaching. Even though the intervention teaching omitted most of

the problem solving, the researcher found that most of the students were still able to solve over 70% of the assigned problems. Therefore, the strategy of reducing problem solving when teaching university physics seems to be applicable. This strategy can save valuable teaching time, which can be used for thinking and discussing.

Meanwhile, 5 students noted that they felt that the teaching was difficult since the lecturer gave questions/phenomena before identifying the corresponding principles/concepts. For example,

The course is a little bit difficult for me, since it is hard to figure out the corresponding principle linked to the described phenomena.

The lecturer does not revise the theories before describing the phenomena, which means that I don't know where I should start to think.

The lecturer usually begins by posing us questions. This is very difficult for me since my background is weak. But, I sense my improvement during these three weeks.

Since the students' physics backgrounds were widely varied, the teaching design could hardly match all the students' abilities. Considering the proportion, 5 out of 53 mentioning their difficulty with the new teaching approach may be regarded as minor. Meanwhile, when some of them addressed their difficulties, they also noted their improvement and implied a gradual adjustment to this approach, which aimed to provide more challenge to the students. Furthermore, the intervention students seemed to be more aware of their background weakness and the complexity of understanding the concepts when expressing their feelings of difficulty. These responses matched the aims of the program design.

With respect to the content structure, six students pointed out that the key points were clear and/or the concepts well integrated, while four criticised the structure as being non-systematic. For example,

The handouts are very helpful, since the key points are clearly listed.

I like the content structure, because it helps me integrate many related concepts.

The sequence of teaching content mismatches the textbook structure. The lecturer should edit a textbook to match her teaching way.

The structure was unsystematic, since the theories jumped here and there. This made it difficult for me to follow because my background is weak.

From the responses, the complaints about the content structure were mainly concerned with the mismatch with the textbook, and the need for a sound physics background. In spite of complaints from a few students, some students noted that the structure helped them integrate concepts and promoted reflection of their prior understanding of the concepts, which matched the goals of the intervention program.

The third finding responded by the intervention students was that 13 students mentioned that the teaching promoted their interest in and/or curiosity about physics. The main reasons for this were the fact that the content included many life examples, and the interactive teaching approach. For example,

The course introduced many examples that we are familiar with in everyday life. This promoted my interest in learning physics.

I like the interactive way of teaching, since it greatly promotes my interest and curiosity.

The fourth comment responded by the intervention group was that 22 students regarded that the implementation of an interactive teaching style as a major strength of the intervention program. These comments are highly linked to the outcome of stimulating thinking and/or participation in discussion. For example,

I like the interactive way of teaching, since this provides opportunities for thinking, promotes our understanding of the concepts, and avoids dozing.

The interaction between the lecturer and the students stimulates our thinking, and then promotes our learning interest.

I like the discussion in class because it can help integrate our concepts.

Discussing with peers helps me realize my misconceptions rather than merely knowing the right concepts.

Discussion can greatly promote our thinking, and thinking is essential for comprehending the concepts.

According to the responses, the students addressed some advantages of the interactive teaching approach. Amongst the 22 students who addressed this

strength, 12 students linked the interactive teaching to promoting thinking and/or participation in discussion; 6 students pointed out the outcome of promoting learning interest and/or avoiding monotony, and 6 students directly related the approach to enhancing their understanding of physics concepts. There were no objecting opinions found, in contrast to such a high percentage (22 out of 53 = 41%) who expressed their appreciation of the interactive teaching approach. The responses imply that the teaching time spent on questioning, thinking, and discussing received the students' praise. This finding may eliminate the lecturers' hesitation to adopt an interactive teaching approach, considering the time constraints (see section 5.4.1).

The last issue raised by the intervention group was that 10 students expressed satisfaction with their learning achievement, and 3 students expressed their hope of keeping the intervention program and reluctance to be shifted back to the traditional teaching model. For example,

The teaching style helps me a lot in clarifying my understanding of the concepts, but some existing misconceptions are so persistent that they are still hard to change.

I like the whole content design. I feel it is enjoyable (in the physics class) and I learn a lot.

I am unhappy that we have just adjusted to and started to appreciate this teaching style, and now we have to be shifted back to the traditional class. That style "may be" (noted by the student) very monotonous and boring.

I have a better understanding of the physics concepts. But, a three-week period (for the intervention teaching) is too short. There is not enough time for us to comprehend a more flexible learning method. Also, we have not organized the concepts well yet.

According to the students' responses, the intervention teaching seemed not only to develop their understanding of the physics concepts but also develop their perspectives of the learning process, and guide them to adopt a deeper and more flexible learning approach.

In summary, the major features of the program and the teaching outcomes mentioned by the intervention students in the open-ended questions are presented in Figure 8.3. Responding numbers are listed with the features and the linked

outcomes.

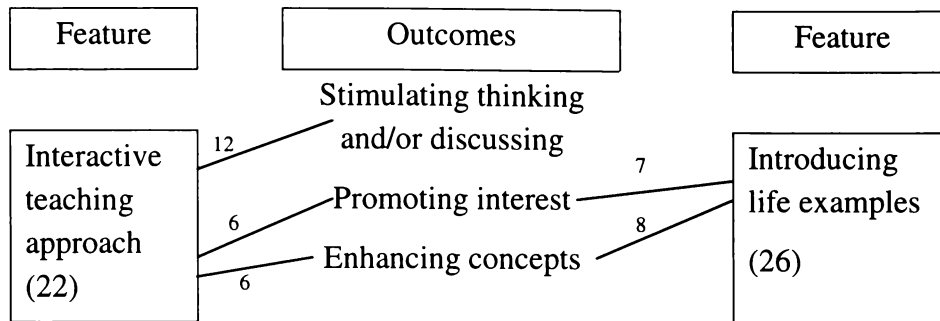


Figure 8.3 Major strengths and outcomes of the intervention teaching according to the responses to the open-ended questions

The two main features, which emerged from the responses to the open-ended question were the interactive teaching approach and introducing life examples. Although both features showed significant links to the outcomes of promoting interest and enhancing concepts, the outcome of stimulating thinking and/or discussing was shown to be related only to the feature of interactive teaching approach. According to the researcher's design, central aims of the intervention program are to engage students' thinking and participation in discussion in class. Therefore, adopting an interactive teaching approach became an important task for fulfilling these aims. Figure 8.3 shows that the students made no direct link between life examples and stimulating thinking and/or discussing. The results imply that simply introducing life examples may fail to engage the students' participation in the learning process. In other words, the modification of the didactic teaching approach is essential for shifting the learners from being passive receivers to active participants in learning physics.

Meanwhile, about 10% of the intervention students complained about the difficulty of the questioning before teaching approach. This was the highest criticism of the intervention students. However, this problem seemed not to deteriorate the students' learning interest or learning confidence (see section 8.1.3). On the contrary, the intervention students gave more positive responses to the questions of promoting learning interest and reinforcing confidence in the closed questions. In addition, the strategy of creating challenge may have promoted the students' awareness of the incompleteness of their prior study and encouraged them to take responsibility for their own learning, ie, the intervention

students were found to be more autonomous than their peers in the traditional classes, as shown by their study hours.

The outcomes of the intervention teaching can be further investigated by comparing these responses with those of the traditional students. Details are discussed in the next section.

8.2.3 Comparing the intervention and the traditional teaching

The third step of the discussion of the students' responses to the open-ended questions is the comparison of the intervention and traditional groups. The responses of the students in the two groups are markedly different. Since the two groups consisted of a very different number of students, percentages are used to reveal the differences between them. In general, the intervention students gave more responses to the open-ended questions than did the traditional students. On average, each intervention student responded with two to three statements, while most traditional students wrote only one statement. Therefore, summations of the responding percentages of all items in the intervention group were over double those of the traditional group.

The major differences found are listed in Table 8.10. Based on Table 8.10, the difference between the intervention students and traditional students can be analysed as follows.

Firstly, introducing life examples was the top strength of the intervention teaching as perceived by the students. About half (49%) of the intervention students pointed out this strength in contrast to only 5% of the traditional group. In the opposing group, 11% of the traditional students complained that there was a lack of life examples, compared with none of the intervention students. The achievement of the intervention teaching in showing relevance to life seems to be very significant compared with the traditional approach. To achieve this goal, the teaching has to reduce the proportion of time spent deriving formulas and problem solving in order to save teaching time for introducing life examples. Meanwhile, lecturers need to search widely through different resources to find material to enrich the information about life examples linked to physics (see section 7.3.2).

Table 8.10 A comparison of intervention and traditional teaching

	Intervention (53 students)	Traditional (327 students)
Introduces life examples	49%	5 %
Lacks life examples	0	11%
Promotes interest/ curiosity/enjoyment	25%	64% (class P) 2%(other 6 classes) ¹
Boring /Tedious/feel sleepy	0	8% (class P) 17%(other 6 classes) ¹
Difficult	10%	1 %
Interactive teaching approach	40%	4%
Stimulates thinking	24%	4%
Satisfaction with learning achievement	19%	1%
Gives lucid lecture	0	10%
Works hard on teaching	0	3%

Secondly, in the area of learners' interest, the intervention group made many positive comments, while the traditional group appeared to vary amongst different classes. As mentioned in section 8.2.1, amongst the seven traditional classes, one class (class P) received many positive responses from the students, but the other six classes' responses tended to be negative. The responses of these three groups: the intervention class, class P, and the other traditional classes, appeared to be very different with respect to their feelings of interest and boredom.

With respect to the six traditional classes, responses of feeling bored, sleepy, and/or tedious was as high as 17% in contrast to only 2% who noted that they felt interest in the classes and enjoyed them. This implies that most of the traditional teaching diminished rather than inspired students' learning interest. On the other hand, as many as 64% of the class P students responded that the class was interesting and/or enjoyable. The lecturer seems to successfully promote most of

¹ Since the students' responses from class P were markedly different from the other six classes, the results from the traditional group are presented in two parts. For more details see section 8.2.1.

the students' learning interest.

The percentage of students in class P who responded that they were interested in the classes (64%) was higher than that of the intervention class (25%). However, the statements from the two groups seemed to differ in their focus. In class P, feelings of interest in the class were mainly based on the lecturer's ability to entertain the students rather than on feelings of interest in the subject matter. Many students in class P mentioned that the lecturer was humorous and had shared his life experiences with them, which is why they enjoyed the class. However, no significant links were found between interest in the class and interest in learning physics. The students noted. For example,

(The class was) quite interesting when the professor talked about his life experiences, but also quite boring when discussing the physics content.

The lecturer is humorous, and the lesson is often appealing, but he seems to spend too much time on topics irrelevant to physics.

As a result, 8% (5 out of 61) of the students in class P noted that the course was sometimes boring, while all of them also noted feelings of interest in the class as well.

In the intervention class, the responses of feeling interested showed a significant link to learning physics. The intervention teaching seemed to attract the students' attention to and interest in the subject matter, rather than focusing on the characteristics of the lecturer (see section 8.2.2).

The third difference between the responses of the two groups was that the intervention students addressed the difficulty of learning physics more than did the traditional group. Approximately 10% (5 out of 53) of the intervention students noted that they felt it was difficult to keep up with the questioning before teaching approach, while only 1% of the traditional students noted the difficulty in learning physics. This comparison implies that the intervention teaching program had promoted the students' awareness of the incompleteness of their prior learning, which matched the aims of the program design (see section 7.2.2). A few complaints from the students about their difficulties with this challenge are perhaps inevitable due to the diversity of the students' background. Also, the

feelings of difficulty may gradually be eliminated when the students become more used to the new teaching approach. Additionally, when the students addressed their learning difficulties, they seemed to attribute this more to the weakness in their physics background rather than blame it on the teaching design (see section 8.2.2). Since the expected outcomes of promoting awareness and diminishing boredom seem to have been achieved, a figure of 10% of students expressing their feelings of difficulty should be acceptable.

The fourth difference perceived by the two groups was that the intervention teaching seems to have achieved its goal of facilitating the students' participation in the learning process. Out of the intervention class, 40% of the students noted that the course implemented interactive teaching, and 24% commented that the teaching had stimulated their thinking and /or discussing. These percentages were much higher than the traditional group, where only 4% noted the adoption of interactive teaching and the strength of stimulating thinking. Therefore, most of the traditional teaching may still be dominated by the didactic teaching style, with many learners lacking intellectual engagement in class.

The fifth difference responded by the two groups was that 19% of the intervention students expressed satisfaction with their learning achievement, in contrast to only 1% of the traditional group. According to these responses, the learning achievement was mainly due to the emphasis on life examples and the adoption of interactive teaching. These two features of the intervention program resulted in promoting learning interest and stimulating thinking, and therefore, greater achievements could be attained.

Finally, a significant number of the traditional students mentioned two strengths of their lecturers' teaching which were completely absent from the intervention group responses. Approximately 10% of the traditional students praised their lecturers for giving lucid lectures, and 3% expressed their appreciation of their lecturers working hard on teaching. None of the intervention students gave any such praise, but neither did they criticise the absence of lucid lectures or of hard work on the part of the lecturers. Teaching effort on giving lucid lectures seemed not to be an issue of concern for the intervention group.

In summary, the absence of responses concerning teaching performance, and the emphasis on participation in the learning process and awareness of their learning weakness instead, implies that the program successfully shifted the classroom focus from teaching to learning. Intervention students' responses matched the intervention program design, which aimed to promote the role of learners from passive receptors to active participants. In agreement with the findings in phase 2 of this research (summarized in section 6.3.2), students' appreciation of the lecturers giving lucid lectures and working hard on teaching may not actually benefit learning achievement. Praise of the lecturers' performance in a transmission method of teaching may exist alongside passive learning attitudes and poor learning outcomes.

8.2.4 Comparing traditional teaching in two consecutive years

The last step in the discussion of the students' responses to the open-ended questions is a comparison of the traditional teaching in two consecutive years.

This research investigated the traditional students' perceptions of the course twice, by open-ended questions: survey 2 in 1997, and survey 3B in 1998. Some events occurred between survey 2 and survey 3B which may have caused modifications to the teaching design and shifted the students' perceptions of the course. These events included (1) The researcher informed the lecturers of the students' perceptions as found in phases 1 and 2 to the lecturers (see section 5.1), (2) The domination of the unified examination was reduced, and lecturers were provided with more authority and flexibility in assessing their students' performance (see section 7.1.2).

Since the number of the participants in each group was similar, simply comparing the responding frequencies can determine the differences between the students' perceptions from one year to the next. The statements of the students in the two consecutive years can be separated into two parts: improved statements and stable statements. The comments which appeared to be more positive in the later survey (survey 3B) in comparison with the earlier (survey 2) are listed in Table 8.11.

Table 8.11 A comparison of the responses to survey 2 and survey 3B
(Comments which appeared to be more positive)

Statements	Responding frequency	
	Survey 2 (330 students)	Survey 3B (327 students) ²
Teaching pace too fast	87	23
Lucid (inarticulate)lecturing	4 (6)	33 (5)
Clarify concepts	9	20
Introduce (lack of) life examples	6 (47)	35 (16)
Interesting	15	54

According to Table 8.11, in comparison with the results of survey 2, survey 3B showed a significant improvement in diminishing the criticism of the fast teaching pace, and enhancing the strengths of clarifying physics concepts, lucid lecture, systematic structure, introducing life examples, and promoting learning interest.

These comments may be linked to each other. Based on the analysis of the correlation coefficients of the data from phases 1 and 2 (see section 4.2), possible links of these improving factors are illustrated in Figure 8.4 and are discussed as follows.

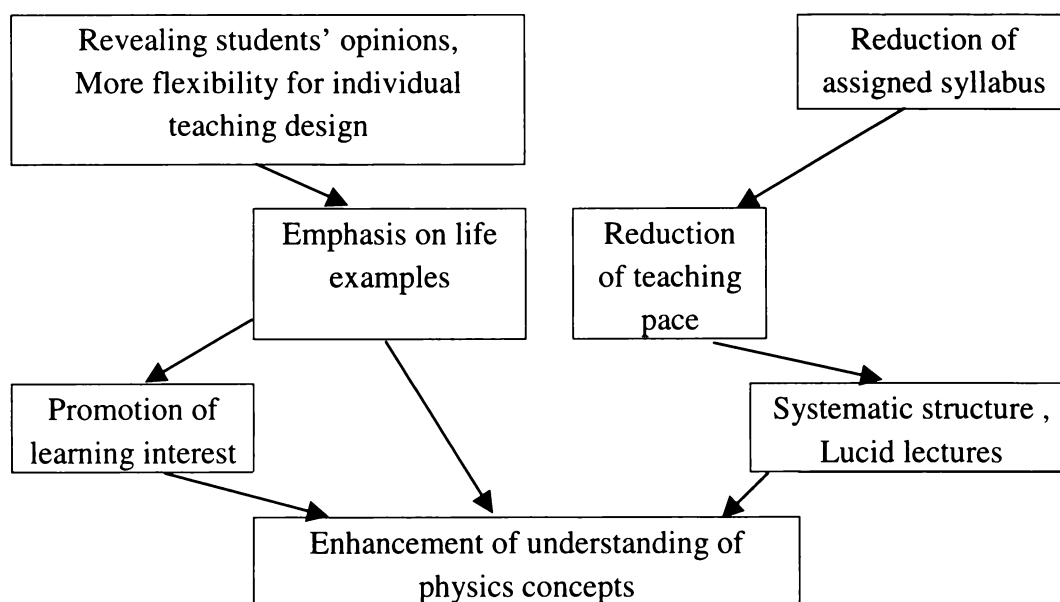


Figure 8.4 Possible links of events to the improvement in the students' perceptions of the course.

² Only the students' responses in traditional classes are analysed.

The teaching pace seemed to be greatly modified to suit the students' learning, which may be the result of the reduction in content coverage. A more reasonable teaching pace may help the lecturers to present in a more systematic and lucid way, thus allowing the learners to better follow the teaching. Meanwhile, provision of more life examples may have promoted learning interest. As a result, the responses of lucid lectures, systematic structure, and promotion of learning interest may all have contributed to the outcomes of clarifying physics concepts. The two events occurred between the two years: modification of the unified examination and informing the lecturers of the students' opinions, may have facilitated the modification of teaching content design by many of the lecturers, thus resulting in the improvement noted by the students.

These promising indicators also provide a positive reflection on the variation of the lecturers' perceptions of content design. As discussed in section 5.2.4, the lecturers' opinions had shifted to be more consistent with the students' expectations, when comparing the investigations of phases 2 and 3. These shifts in opinion included reducing the teaching pace, reducing problem solving, and placing emphasis on everyday life examples.

The researcher suspected that the adjustment in the lecturers' opinions might have been partly due to this research. Firstly, the researcher's revelation of the students' opinions to the lecturers might have helped the lecturers to have a better understanding of their students' expectations (see section 5.6.2). Secondly, the lecturer interviews, which were conducted in phase 2, might have promoted the lecturers' awareness of and reflection on their teaching outcomes and teaching environment, and may have indirectly triggered the modification of the unified policy, which had existed for 15 years (see section 5.2.1).

In summary, when comparing the teaching design of the two years, the students' responses indicated significant improvements in several areas, and these improvements matched the change in the lecturers' opinions regarding content design.

However, according to the students' responses, the improvements seemed to be merely limited to the area of teaching content design. There were some statements

which appeared to have no or very little improvement when the responses to surveys 2 and 3B were compared. The results are listed in Table 8.12.

Table 8.12 A comparison of the responses to surveys 2 and 3B
(Statements with no or insignificant improvement)

	(N=330) Survey 2	Survey 3B (N=380)
• Boring/ tedious/ feel sleepy	74	51
• Lack of interactive teaching/didactic teaching	12	14
• Lack of thinking	5	13
• Too repetitive	9	9

Statements which showed no significant improvements in the two years are listed in Table 8.12. These statements include the feelings of boredom, didactic teaching, lack of thinking and repetition.

The primary reasons may be that the lecturers remained committed to a traditional didactic way of teaching approach, and adopted a teaching strategy which avoided challenging to the students. This type of teaching approach is likely to fail to engage the students' thinking in class, and result in feelings of boredom and repetition.

Meanwhile, it shows that although the responding frequency of feeling interest was dramatically increased between surveys 2 and 3B, the criticism of feeling bored seemed not to diminish as significantly as the increase in interest. The feeling of boredom may have resulted from the teaching approach in addition to the teaching content design.

Therefore, the didactic teaching approach needs to be modified in order to promote learning engagement.

In summary, the students' evaluations of the course showed improvement in those areas directly linked to content design, but little improvement in the areas related to teaching approach. The shift/consistency of the students' evaluation of the course in the two different years is in accordance with the modification/persistence of the lecturers' perception of the course design. This

finding highlights the role of lecturers' perception in the learners' evaluation of the course. This finding matched the notion discussed in section 6.4.3 where it was noted that in order to improve the teaching outcomes, developing the lecturers' perceptions may be more fundamental than improving teaching techniques.

8.3 Further discussion of the outcomes of the intervention program

In this section, further discussion of different aspects of the outcomes of the intervention is presented under six headings:

- (1) affective outcomes versus academic achievement,
- (2) teaching content versus teaching approach,
- (3) advantages of the interactive way of teaching,
- (4) enriching students' perceptions of learning,
- (5) avoiding passive attitudes and reducing the number of high-risk students, and
- (6) teacher development.

8.3.1 Affective outcomes versus academic achievement

The first aspect of the data analysis of the intervention teaching was that the program greatly improved affective learning outcomes, but there was no evidence to show improvement in the students' academic achievements.

According to the results of the closed questions, the intervention class agreed much more strongly with the items of content induced learning interest, teaching approach avoided monotony, feeling of satisfaction and enjoyment of the course overall. Differences between the intervention class and the traditional classes for these four questions were significant at $p=0.05$.

However, in the area of academic achievement, there was no evidence to show

that the intervention teaching had directly benefited the students. The intervention students' responses to the question of whether the class enhances physics concepts were not significantly different from those of the students in the traditional classes.

Meanwhile, in phase 3 of this research, the researcher had distributed two sets of standardized tests to the intervention class and two traditional classes, in order to examine their achievements in academic performance. Details of the test design are described in section 3.3.1. The academic tests consisted of a pre-test and a post-test, and the results are listed in Tables 8.13 and 8.14.

Table 8.13 A comparison between intervention and traditional teaching in achievements of concept understanding

Class average	Force concept test		
	Pre-score	post-score	Gain %
Intervention	61	64	9 %
Traditional A	60	64	10 %
Traditional B	66	72	15 %

Table 8.14 A comparison between intervention and traditional teaching in achievements of problem-solving

Class average	Problem-solving		
	pre-score	post-score	Gain %
Intervention	47	50	6 %
Traditional A	49	51	5 %
Traditional B	53	57	8 %

The above tables list the results of the pre-tests, post-tests, and the gain percentages between the two tests. The gain percentage is noted by "Gain%" in Tables 8.13 and 8.14, which is based on Hake's (1997) definition:

$$\text{Gain \%} = (\text{postscore} - \text{prescore}) / (100 - \text{prescore})$$

According to the above equation, gain percentage indicates the proportion of what

the students have obtained in relation to what they did not previously understand, as indicated by the pre-test.

As can be seen from the above two tables, the academic background of the intervention students was consistent with that of traditional A in both the concept test and problem-solving. This result is reasonable because these two classes had the same major. Traditional B had a stronger academic background compared with the other two classes.

According to the post-scores and the gain percentages in both the concept and the problem-solving tests, traditional B performed slightly better than traditional A and the intervention class. The outcomes for traditional A and the intervention class were consistent. Therefore, the results of the tests do not provide any evidence of the intervention program improving academic achievement.

Regardless of the slight differences between the classes in academic achievement, the academic achievements overall are far from satisfying. The gain percentages appear to be as low as 5% to 15%. This indicates that although the lecturers had covered all the topics, the students had picked up less than 15% of the teaching content. The low gain percentages may challenge some lecturers who regard content coverage as one important task of the teaching design. Due to these poor gain percentages, the lecturers should be more concerned about how well the students have learnt than how much should be covered.

To encourage the students' involvement in answering the tests, the results of the post-tests were counted as part of their grades (Rennie and Punch, 1991). Therefore, the poor results of the post-test should reflect their actual learning achievement and should be seen as a warning signal. As a lecturer noted regarding the results of the post-tests:

This result is really frustrating. I can hardly see any progress in the students' (academic) performance after nearly two months of teaching. I think there are many things which should be reconsidered (in the teaching design).³

³ Personal communication by email.

Possible reasons for the intervention teaching not producing any positive results in the academic tests are discussed below. Firstly, the tests included a wider scope of content than that covered by the intervention teaching. The tests covered the whole subject of linear mechanics which had taken seven teaching weeks, while the intervention program took only three of those seven weeks. Secondly, the test questions were presented in a traditional style, which is dominated by theory, while the questions discussed in the intervention program were extracted from everyday life phenomena. The different contexts of the questions may have hindered the intervention students' performance in the tests. Thirdly, the significant affective learning outcomes of the intervention teaching may need more time to influence learning attitudes and learning strategies, and therefore manifest themselves in the students' academic performance. The students' learning attitudes and strategies will be discussed later in section 8.3.4.

8.3.2 Teaching content versus teaching approach

The second aspect of the data analysis of the intervention teaching was that the outcome of the program was more significant in teaching approach than in teaching content.

In response to the closed questions, the interactive teaching approach, which aimed to provide more challenge and opportunities for students to participate in the learning process, received strong praise from the students. Approximately 80% of the intervention students agreed that the teaching approach had (1) been aware of learning outcomes, (2) avoided a didactic way of teaching, (3) avoided monotony, and (4) engaged the students in discussion, which appeared to be much higher than the traditional group. In the area of content design, although the intervention program received better evaluation from the students than the traditional classes for promoting interest and introducing life examples, but little difference was found for clarifying key points and integrating concepts. Therefore, the outcomes of the intervention teaching for aspects of teaching approach were more significant than those of content design, in comparison with the traditional group.

Similar results were also found in the open-ended questions. The intervention

teaching received praise from as many as 40% of the students for the interactive way of teaching, and this new teaching approach was shown to be decisive in engaging the learners in thinking and discussing, and in avoiding feelings of boredom. Meanwhile, when the intervention students appraised the new teaching style, many of them seemed to be critical of the didactic way of teaching and expressed their reluctance to be shifted back to traditional teaching after the completion of the program. In contrast, the need for modifying the didactic teaching approach seemed to be minor as perceived by most traditional students. Less than 10% of the traditional students made comments, either positive or negative, regarding this issue in response to the open-ended questions. The minimal concern of the traditional students with respect to the didactic teaching, which was in accordance with their predecessors as well as the lecturers, may have been influenced by the superficial transmission view of learning (see section 6.1.3).

The advantages of the interactive way of teaching are further analysed by evaluating the correlation coefficients.

8.3.3 Advantages of the interactive way of teaching

The third aspect of the data analysis of the intervention program is the advantages of the interactive way of teaching. Possible advantages of the interactive teaching approach can be identified by calculating the correlation coefficients, which are discussed as follows.

Firstly, in response to the closed questions, the students' preferences for the interactive teaching approach have shown to be negatively correlated to agreement that their lecturers' teaching was limited to one-directional transmission. The correlation coefficient between these two items was $r=-0.31$. This implies that the more interactions the lecturers stimulate in class, the more the students favor this type of teaching approach.

Secondly, the involvement in discussion in class was the highest correlated, compared with other items, to stimulating thinking. The correlation coefficient between involvement in discussion and stimulating thinking was $r=0.48$. Other

items such as introducing life examples and providing key points were also significantly correlated to stimulating thinking, but their correlation was comparatively lower. The relations are shown in Figure 8.5.

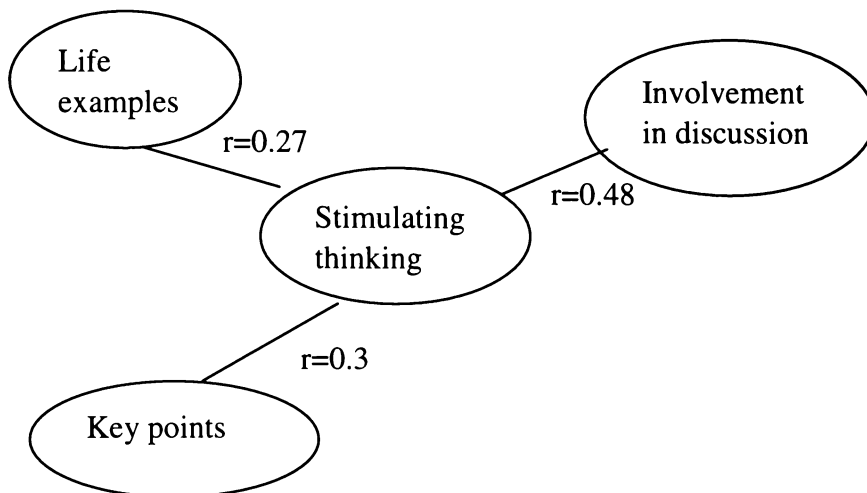


Figure 8.5 The correlation coefficients between stimulating thinking and other items.

Finally, the links between stimulating thinking and the learning outcomes, either affective or cognitive, were more significant than those between life examples and the learning outcomes. The coefficients of both stimulating thinking and life example, correlated to the learning outcomes are shown in Figure 8.6.

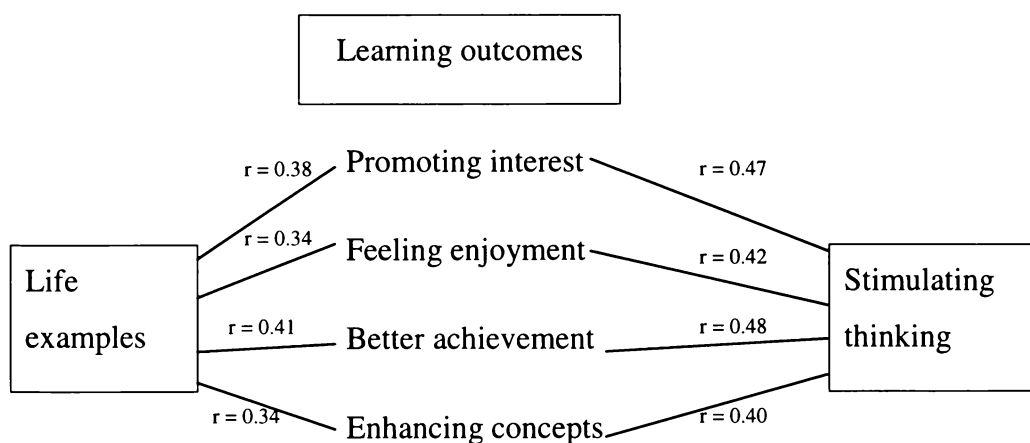


Figure 8.6 Correlation coefficients showing that stimulating thinking has stronger links than life examples to learning outcomes

The results shown in Figure 8.6 highlight the necessity of stimulating students'

thinking in order to achieve better learning outcomes. Compared with providing life examples, stimulating thinking is more crucial to the learning outcomes, not only in cognitive but also in affective aspects.

The correlation has highlighted the crucial role of engaging the students in discussing and thinking, and the necessity of a modification of the current didactic way of teaching. As discussed in section 5.4.1, the physics lecturers stated several existing barriers to implementing an interactive teaching approach and regarded this new teaching approach as practically unfeasible. The intervention program has shown that these barriers are not insurmountable. With the same teaching resources and under the same administration limitations as the traditional classes, the intervention program successfully engaged the students in discussions and greatly stimulated their thinking.

8.3.4 Enriching the students' perception of learning

The fourth aspect of analysis of the intervention teaching was that the program seemed to have enriched the students' perceptions of learning.

The intervention teaching may have shifted the students' perception of their role, as learners in class, from passive receptors to active constructors. In response to the closed questions, the intervention students expressed more agreement with engagement in discussion (81%) and in thinking (83%) than in listening (79%), while the traditional students agreed more with listening (69%) than with engagement in discussion (32%) and thinking (65%). Engagement in discussion and thinking can be categorized as active participation in learning while listening is regarded as passive reception. The comparisons between active participation and passive reception with respect to the two groups of students are presented in Table 8.15.

Table 8.15 Comparison between active construction and passive reception

		Intervention (agree %)	Traditional (agree %)
Active participation	Discussion	81	32
	Thinking	83	65
Passive reception	Listening	79	69

At the same time, the intervention program seemed to have successfully shifted the students' focus from teaching to learning. In response to the open-ended questions, the majority of the intervention students made comments related to their learning, either positive or negative. As discussed in section 8.2.2, the intervention students' responses mainly focused on their engagement in learning, their learning achievement, and the difficulties they encountered. Meanwhile, when the intervention students commented on the teaching, their praise/criticism usually referred to their learning. However, a considerable number of the traditional students made positive appraisals of the teaching performance and commitment, without linking it to their learning outcomes (see section 8.2.1).

Furthermore, the intervention teaching seemed to have developed the students' learning capability. In answer to the closed questions, significantly more of the intervention students compared with the traditional group agreed that the new style of teaching (1) reinforced learning confidence ($p < 0.05$), (2) developed thinking ability ($p < 0.05$), and (3) developed deeper learning strategies ($p < 0.001$). Agreement that the teaching style helped to develop deeper learning strategies was also underpinned by the students' responses to the open-ended questions, where some intervention students expressed their awareness of deficiencies in their prior learning, and commented on the complexity of understanding the physics concepts (see section 8.2.2). Learners' awareness of their background weakness can promote learning motivation, and awareness of the complexity of learning the subject knowledge can activate the learners to adopt a deeper-level of learning strategy (Baird, 1986). Although the academic tests showed no significant difference in academic achievement between the traditional and intervention classes, the development of learning capacity, including confidence, thinking

ability, and learning strategy, should be beneficial to their learning achievement in the longer term.

8.3.5 Avoiding passive attitudes and reducing the number of high-risk students

The last aspect of data analysis of the intervention teaching is that the program might not only benefit the students who hold positive learning attitudes towards the course, but it may also greatly eliminate the opposing group who might potentially hold negative opinions of the course and possess passive learning attitudes.

As found in phases 1 and 2, both the students and the lecturers regarded passive learning attitudes as the main reason for unsatisfactory academic achievement (summarized in section 6.2.2). Meanwhile, as analyzed in section 4.2.3, the students' responses indicated that learning attitudes and strategies are not isolated factors, which depend only on the individual student, but rather, are deeply influenced by instruction styles. Negative perceptions of the course may be crucial in determining passive learning attitudes. Therefore, negative perceptions of the course and passive learning attitudes can be regarded as indicators of high-risk students who are likely to fail the course.

Negative perceptions of the course and passive learning attitudes which may be regarded as indicators of high-risk students are listed along with the agreement percentages with respect to both the intervention and traditional groups in Table 8.16.

Table 8.16 Indicators of high-risk students

		Intervention	Traditional
	• Learn nothing from the course	0	8%
Value of the class	• Will not attend if not compulsory	2%	12%
	• Feel bored in class	0	15%
Attitude	• Minimum effort to pass	9%	16%
Effort	• Study no more than 1 hr/wk	2%	37%

According to Table 8.16, 8% of the traditional students agreed with the strong criticism of learning nothing from the university physics course, whereas no intervention students agreed with this statement. When a student feels that he or she has learnt nothing from a class, it will be unlikely that she or he will attend the class unless attendance is compulsory. As high as 12% of the traditional students acknowledged that they would not attend the physics class if it was not compulsory, in comparison with only 2% of the intervention students. These two perceptions, learning nothing and non attendance, may indicate the students who have completely denied the value of the physics class.

With respect to the students' learning expectations, 16% of the traditional students, in comparison with 9% of the intervention students, responded that they had no interest in learning physics at all, and expected to put in no more effort than was required to pass. This group of students might have experienced little of value from the course, either in the areas of developing knowledge or cultivating learning capability, and thus they regarded it as unnecessary to put in more effort than was required to pass.

In response to the open-ended questions, 15% of the traditional students commented that the physics class was boring, compared with none of the intervention class students. At the same time, over one third (37%) of the traditional students said that they studied no more than one hour per week out of class, while the intervention class drastically reduced the low commitment group to only 2%.

The failure rate at Feng-chia University has remained as high as around 30%, despite the fact that many lecturers claimed that they had greatly reduced the difficulty of the course (see section 5.5.2). Although the lecturers had noticed the links between passive learning attitudes and unsatisfactory academic performance, they did not expect to eliminate this major learning barrier through their teaching.

However, based on the above discussion, the intervention teaching has been shown to have greatly reduced the students' negative perceptions of the course, including learning nothing and feeling bored, and eliminated the potential reluctance of engagement in learning, including attempts to skip class, minimum

effort to pass, and low study hours. Through the design, which provided more challenge, showed relevance, and encouraged participation in the learning process, the intervention program has been shown to be not only beneficial to the students' perceptions of the course, but also advantageous to promoting learning motivation, attitudes, and the actual effort applied by the students.

8.3.6 Teacher development

The final finding of the outcomes of the intervention program was in fact beyond the researcher's expectations when designing the program. The teaching of the two lecturers, TL and YL, was found to be considerably improved when comparing their students' responses in surveys 2 and 3B. As explained in section 7.1.1, the researcher had much communication with both TL and YL before implementing the intervention program, and the researcher suspects that the communication procedure contributed to their improvement in teaching. Therefore, their achievement can be regarded as an indirect outcome of the program.

In the closed questions of survey 2, the two classes taught by TL and YL were ranked at around the middle for most of the questions including teaching style is appealing, very difficult to undermine my confidence, adopting a deeper learning method, etc. In comparison with the results of survey 3B, amongst the seven participating classes, these two classes were ranked in the top three for many questions, specifically: (1) avoiding one-directional delivery, (2) involvement in discussion, (3) awareness of learning outcomes, (4) deeper learning, (5) feeling satisfied, (6) promoting interest, (7) developing thinking, (8) enjoyment and (9) reinforcing confidence. Therefore, there seems to have been an apparent improvement in the teaching outcomes of both TL and YL between survey 2B and survey 3, compared with the other lecturers.

Meanwhile, the nine items mentioned above might provide some hints to help explain the main reason why TL and YL's students gave a better appraisal of the teaching than the other traditional classes. The main reason may be due to their efforts to modify their original didactic teaching approach. In addition to the findings discussed above, the effort TL and YL put into encouraging interaction in

class was also noted in the responses to the open-ended questions (see section 8.2.1). Although the students' commented about TL and YL's interactive teaching were not as positive as those of the intervention students, the interaction in these two classes was still greater than in the other traditional classes.

According to their achievements in the areas identified above, some possible links can be suggested, as illustrated in Figure 8.7.

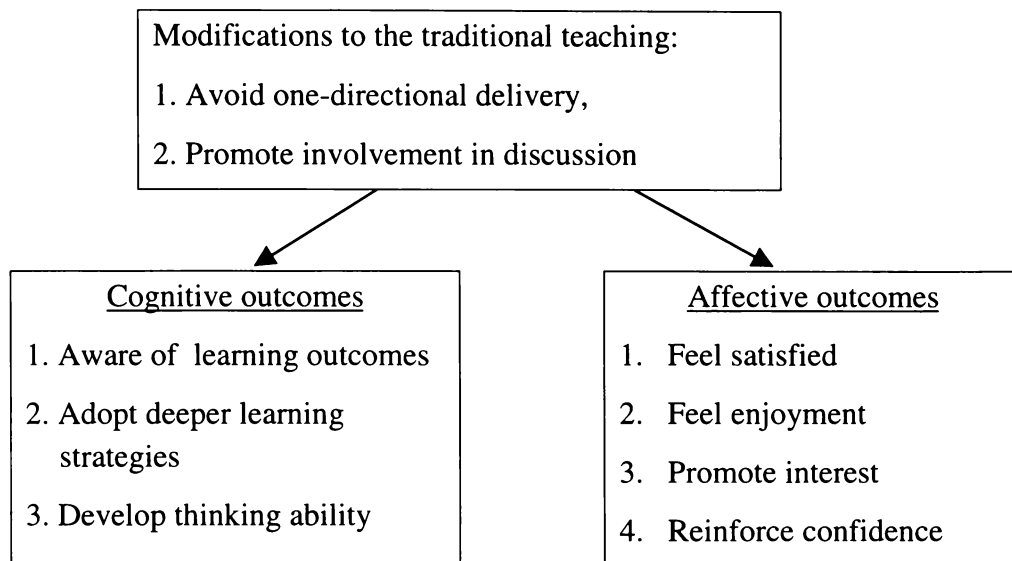


Figure 8.7 Reasons and outcomes of teaching improvement in TL and YL's classes

According to Figure 8.7, more students in TL and YL's classes than in the other traditional classes agreed that the teaching eliminated didactic teaching methods, by avoiding one-directional delivery and promoting involvement in discussion, and this modification may have contributed to the learning outcomes both in affective and cognitive aspects. For the cognitive learning outcomes, the more interactive teaching approach appeared to be beneficial for (1) developing awareness of learning, (2) encouraging students to adopt deeper learning, (3) developing students' thinking ability, and (4) reinforcing learners' confidence. In addition, possible affective outcomes resulting from the new teaching approach were feeling enjoyment, feeling satisfied, and promoting interest. The above assertions based on TL and YL's achievements are fairly consistent with the discussions of the correlation coefficients (see section 8.4.3). Both sets of discussions highlight the essentiality of modifying the didactic teaching approach

in order to improve learning outcomes.

The adjustment of TL and YL's teaching may have been partly influenced by the researcher. As explained in section 7.1.1, the researcher had explained briefly the pedagogical theories and the understanding of the existing teaching situations to them in order to receive permission for the implementation of the intervention program. Meanwhile, both TL and YL expressed great concern about the problems with the current teaching design and had exchanged their opinions with the researcher about possible ways of improving the learning outcomes. These conversations might have promoted their awareness of the necessity of modifying the didactic teaching. Since TL and YL experienced better outcomes due to this new teaching approach, these improvements can be expected to encourage them to continue modifying their didactic teaching approach further in the future.

The improvements found in TL and YL's classes were very surprising to the researcher. Based on the findings in phases 1 and 2, the researcher found that most of the lecturers viewed learning as a process of transmission and hence expressed little interest in attempting to modify their teaching approach when discussing efforts to improve learning. It seemed to be a very challenging task to convince them of the crucial role of modifying the didactic teaching approach in order to improve their teaching. However, the adjustment of TL and YL shows that the task of convincing the lecturers to put effort into promoting interaction in class is perhaps achievable. Meanwhile, as mentioned in section 7.6.1, in order to make a comparison between traditional teaching and the intervention teaching, the researcher had requested that TL maintain his original teaching style in his class, and received his agreement. However, his students' responses showed that TL's teaching was markedly different when compared with his previous teaching approach as found in survey 2. This result implies that it can be difficult to refrain lecturers from adopting a teaching approach which they believe to be more beneficial to learning outcomes.

8.4 Summary of the findings of the intervention teaching program

The findings of the quantitative evaluation of the intervention teaching program can be summarised as follows.

Firstly, the outcomes of the intervention program were found to be significant in promoting the students' affective responses towards the course, developing the students' perspectives and awareness of learning physics, and promoting the students' participation and engagement in classroom activities, as well as their learning commitment out of class. However, the students' academic achievement was found to be similar between the intervention and traditional groups.

Secondly, the teaching strategy of creating challenge may have contributed to promoting the students' awareness of the needs for learning the university physics course, avoiding feelings of repetition and boredom, and thus promoting learning motivations. In addition, this program found that the teaching design creating challenge may not necessarily undermine but may in fact reinforce learning confidence.

Thirdly, the results also highlighted the critical role of the interactive teaching approach in promoting learning outcomes, either cognitive or affective. Meanwhile, the interactive teaching approach may also broaden the students' perspectives of their own learning. To achieve an interactive teaching approach might be very difficult as many lecturers claimed that they have tried before but mostly failed (see section 5.3.1). However, the outcomes of this interactive teaching were so positive that all efforts to implement interactive teaching are certainly worthwhile. To successfully adopt an interactive teaching approach may be similar to a nuclear reaction- although the threshold energy is unavoidably high, once the reaction is triggered, the power created by the reaction will be much stronger than the power required to trigger it.

Finally, a surprising result was the change in TL and YL's teaching, which may have been partly due to communication with the researcher. Their improvement gives hope for the implementation of the notions of physics education research in

physics classes. In order to facilitate teacher development, broadening the lecturers' perceptions of viewing learning is more important than developing their teaching skills.

The discussions included in this chapter are based on a quantitative evaluation of the intervention program. The next chapter will describe the qualitative evaluation of the intervention in order to provide a better insight into the outcomes.

Chapter 9

Evaluating the intervention teaching (Part II): A qualitative investigation

This chapter is to discuss the students' opinions and comments with respect to the intervention teaching design. Fourteen students in the intervention class were interviewed during the intervention teaching period, and four of them had a second interview after the completion of the intervention teaching. Details of the interview question design are presented in section 3.4.1.

From the interviews, four aspects of the students' responses can be discussed:

- (1) teaching content,
- (2) teaching approaches,
- (3) perceptions of learning, and
- (4) summary of the intervention program.

9.1 Teaching Content

With respect to the design of the teaching content in the intervention teaching, the students' responses can be discussed with respect to two aspects: content selection and content structure.

9.1.1 Content selection

The key elements of content selection in the intervention teaching were: (1) a reduction in mathematics, (2) the linking of physics to everyday life, and (3) a concept test.

- *A reduction in mathematics*

All fourteen interviewees commented that the intervention teaching content was

primarily devoted to enhancing physics concepts but introduced very little mathematics in deriving equations and problem solving¹. Most of them commented that shifting the focus of physics teaching from mathematics to concepts is preferred, and no negative opinions were found. Details of responses from the interviews are grouped and listed with some quotes as follows:

- (1) Most of the students (12 of the 14 students) commented that the physics class focusing on clarifying concepts instead of mathematical derivation is preferred.

Your teaching is very different from my high school physics teacher's. You always teach us physics concepts but with not so many problem examples. This is what we really need because concept is our major weakness. To really understand the physics concept needs much effort. (S8)

- (2) Seven students noted that their main obstacles in solving physics problems were the physics concepts, not the mathematics skills.

It appears that we need many skills in mathematics to solve those problems, but actually our main barrier to solve the problems is (incomplete) physics concepts, not (insufficient) mathematics skills. (S6)

- (3) Most of the students (12 of the 14) felt that they had no difficulty solving the problem assigned, even though the lecturer (researcher) spent very little time on practicing examples.

I don't feel it is difficult to solve the problems in the assignments because I can easily find hints from the textbook when I have difficulty. Although you did not teach us how to solve (the problems), you taught the concepts. (S4)

- (4) Six students suggested that physics lecturers could give most of the problems as assignment and spend very limited time on teaching problem-solving skills.

I prefer your content (selection) to that of my high school physics teacher; you teach very little on problem solving but focus on concepts. The mathematical skills are not really difficult to us; we are able to find the solutions from the examples in the textbook. (S7)

I agree with him (S7) that calculations of the problems can be done by ourselves after lessons. Teaching should not waste time on showing the

¹“problem solving” indicates practicing the exercises in the text or at the end of each chapters, which mainly require complicated calculations and combine concepts and formulas.

whole calculation process, just point out the main key points. (S8)

(5) Nine students commented that when the teaching focused on deriving formulas and on problems, they regarded it as boring and paid less attention.

Our high school physics teacher spent most of the teaching time on solving problems; it was really boring; most of our classmates just did their own work or fell asleep. (S10)

In our high school physics class, not many of my classmates concentrated on the teaching because the teacher was too focused on problem-solving. (S6)

All the responses in the five groupings were positive. There were no opposing responses toward any of the statements in the interviews. However, the positive views from the interviews do not completely match the responses of the student survey.

From the results of survey 3B, six of the 53 students in the intervention class noted, in the open questions, that they had difficulty dealing with the problems assigned and expected lecturers to teach more skills of problem solving (see section 8.2.2).

However, taking together the students' responses in both the interviews and the survey, there were only a few students who expected the lecturer to provide more help in skills of solving problem, and their responses can be regarded as a minority. Most students preferred the shift of the teaching focus from problem solving to concept clarification.

The concept-oriented teaching is very different from most university physics classes which spend the major teaching hour deriving formulas and problems (Amato, 1996). The intervention teaching students' opinions were consistent with the findings of many physics education researchers (eg, Gautreau and Novemsky, 1997) as well as the suggestions of physicist authors (eg, Amato, 1996; French, 1988).

However, the existing teaching content selection mismatched with the students' expectations as well as with the viewpoints of the authors of many physics education articles. This research has found, in phase 2, that the existing teaching in physics classes in Feng-chia was still focused on solving problems (see section

4.1.4).

Possible reasons that existing physics classes were still focused on teaching mathematics were:

- (1) Physics lecturers tend to regard practicing mathematical skills as one important task of university physics courses (Jones, 1997);
- (2) Most textbooks focus on problem solving (Amato, 1996; Gordon and Aubrecht, 1989);
- (3) Interpreting physics concepts/theories requires not only repeating the definitions verbatim but also providing many different contexts linked to the real world (Hewitt, 1998). These contexts are not sufficiently supplied by the textbooks and need lecturers' commitment to search through all possible resources.

The intervention teaching design also included two key elements to help students clarify their concepts in physics: application examples in everyday life, and concept tests. The two components were often combined in the intervention teaching. The students' responses to the two elements are discussed below:

- ***The linking of physics to everyday life***

All 14 interview students noticed that the intervention teaching had introduced many examples from everyday life in the teaching of physics, and all of them mentioned that everyday life examples attracted their attention; for example:

You usually provide the real stuff (demonstration) to us and discuss the phenomena that we are familiar with in our (everyday) life... Many links to life make us feel interested in learning. Your teaching is not like my high school physics teacher. He only kept writing on the blackboard and talking. That kind of teaching makes us feel the lesson is too long to bear. (S10)

Nine students mentioned that the everyday examples made it easy to understand the theory and helped enhance their understanding of physics concepts; for example:

From the life examples, I find it easier to understand the physics concepts and I can remember the concepts for longer. (S11)

Nine students also pointed out that examples linked to life promoted their interest because they could learn practical usage from the information; for example:

The examples that you provided to us made us think about the reasons for many familiar phenomena. It is good to learn something practical not just theoretical. When I feel I am learning something useful for my life, I feel more interested in learning... In high school, we learnt only theories, but we did not know how to link those theories with the phenomena in our lives. (S11)

Twelve students mentioned that life examples made them feel that their physics class was enjoyable and promoted concentration; for example:

I liked the unit on car safety; it was nice to learn something useful for our real life from physics. The unit made me feel fresh since I have never learnt similar material in high school physics. Your physics class is the most attractive subject to me amongst all subjects. I enjoy your teaching very much. Teaching time always passed quickly in your class. Physics lessons are no longer boring and a time for dozing as I experienced in high school. (S9)

- *A concept test*

The intervention teaching also included the use of concept tests. The concept test was an important tool to stimulate the students to be intellectually active and participate discussions in order to enhance their understanding of physics concepts. The researcher provided 4-7 questions to students in each lesson. The criteria of selecting the questions are described in section 7.3.3.

Although the results of the concept test were not marked, almost all interviewees (13 of the 14) claimed that they had engaged in thinking and discussing the questions. The perceived advantages of concept tests are discussed as follows with relevant quotes.

- (1) Ten of the students commented that the concept tests have promoted their engagement in thinking and /or discussing about physics concepts. For example,

I believe that all our classmates think deeply when answering those concept questions. When a correct concept is stimulated in our brain, we will feel proud of ourselves, and the concepts can be held in our mind for a long time. (S9)

Many of our classmates have poor study habits; they hardly ever study after class. The concept tests in your class can help these students at least think

about the concepts in the class. (S6)

It is good that you provide us space (questions and time) to think. I believe that all students in our class are engaged in discussing during the concept test, though some of us may not know the direction (of thinking and discussing)... The purpose (of the concept test) should be the process (of thinking and discussing) and not just getting the right answer. (S7)

- (2) Seven of the 14 students stated that the concept test was helpful to maintain concentration.

I often have trouble to focus my attention during lessons since high school. But the time when I concentrated the most was when I was thinking (and answering) the concept questions.. I like the time that you give us to think, and I like the challenge to see what I did and did not understand. (S1)

- (3) Six of the 14 students noted that concept tests establish their awareness of their learning weakness and achievement.

The questions (in the concept test) looked so simple when we answered them. But I was so surprised that most of us often get it wrong. This makes me feel aware of my weakness in physics concepts and pushed me to study really hard after class. I want to pick up those concepts quickly. In high school, I almost learnt nothing from my physics course, but I just did not realize my problems. (S10)

Although, I could sometimes get the right answers (in the concept test), I found that I could not explain the reasons clearly as you have illustrated to us. This made me realize that I did not really completely understand the concepts. (S12)

- (4) Seven of the students commented that concept questions provided them with the opportunity to identify what misconceptions they need to address.

Although the topics are not new to us, I think we are all situated halfway in between understanding and not understanding. The problem is that we don't know what our defects in physics concepts are. The concept questions can help us to figure out which concepts we need to put more effort into understanding. (S5)

Physics should not be so difficult (as many students think). The subject does not need you to memorize many trivial details as chemistry does and does not need you to practice many solving skills as mathematics does. Physics just needs us to have a clear understanding of a few basic concepts. But the main problem for us in learning physics is that we don't know what we really have understood and what we haven't. The concept questions are very helpful for us to find out the unclear concepts (in our minds). (S3)

- (5) Ten of the 14 students said that the concept tests enhanced their understanding

of physics concepts.

The concept questions helped me a lot in understanding deeper the physics concepts. It is much more effective (to learning outcome) than to just keep “dumping” a lot of information on us as my high school teacher did. In high school (physics class), I worked very hard in copying the notes, but eventually, I still received a very poor score in physics in the Entrance Examination. (S4)

None of the students gave opposing opinions to any of the five advantages just discussed. Interview students’ responses matched the researcher’s expectations when designing the concept tests for the intervention teaching (see section 7.3.3).

On the other hand, in the traditional physics classes, the learning activities are limited to mainly listening to the lecture and copying notes, and occasionally, watching the lecturers’ demonstrations. These activities often result in students being only passive receptors and fail to engage their participation in the learning process. Physics lessons were perceived as boring by many students from the results in phase 2 of this research (see section 4.2.1). Cannon (1988) noted that in traditional unique-directional lecturing, students’ attention declines rapidly up to about 20 minutes after the lecture begins. From the students’ responses, answering the concept questions could help them maintain concentration as well as promoted their engagement in thinking.

Meanwhile, in phase 2 of this study, many students complained that the teaching topics in the university physics course have already been taught in high school despite their poor performance in university physics (see section 4.2.1). Most of the students appeared to be ignorant of the gap between knowing the terminology and understanding the concepts behind it. Although students have learnt mechanics in high school, most of them did not completely understand the physics concepts (see the students’ pretest in Force Concept Inventory in section 8.3.1). Therefore, most physics lecturers still teach mechanics in the university physics course. They have adopted similar content and a similar teaching approach repeating again the what and how that high school physics teachers have already taught the students, and as a result, this way of teaching fails to enhance the learners’ understanding of the concept. Teaching in university physics should put more emphasis than in high school on helping students to realize which concepts

they do not fully understand. Then, the learning can be focused on the persistent alternative conceptions in students' minds. Concept tests can help learners notice their weakness in physics concepts and identify their alternative conceptions.

In summary, since the concept tests were found to successfully help the learners to be engaged in thinking and discussing, to maintain attention, to establish awareness of their weakness in concepts and to realise the complexity of learning physics, then enhancement of their physics concepts should have been achievable.

9.1.2 Content structure: Concepts embedded by context

The second aspect of teaching content mentioned by the students was the structure of the content. In the intervention, the researcher adopted a teaching content structured by context rather than the structure of discipline. The context structure in this research means that one context was chosen from everyday life phenomena for each teaching unit, and several physics principles linked to the context were discussed within the unit.

Details and the expected advantages of the context-structured content are described in section 7.3.4.

Although many interview students pointed out criticisms and suggestions, most of them still preferred the new context-embedded structure to the traditional one. When asked which structures they would choose if they were allowed to, seven selected the context structure and only one preferred the structure of the discipline²; for example,

I would prefer your structure because the traditional structure (in high school) has been shown to fail me. Changing to a new structure may be helpful to my learning. (S4)

Certainly, I will choose your structure, because this kind of structure makes more sense to me. (S9)

I think your structure is more suitable to my study habits (than the structure of discipline). I prefer to learn all theories linked to the phenomenon as you

²Among the 14 interviewees, only eight of them were asked directly by the researcher to select a structure they preferred.

structured the content, because it makes me feel learning is complete (as a whole), not discrete (in pieces). (S13)

To most Taiwanese students, the structure is new, unexpected and unusual. None of the interviewees have ever been taught by the context structure. All of them were used to following the textbook structure that is based on the structure of the discipline.

Although most of the students commented that they liked the use of everyday context, they did experience difficulty with the approach. Both the positive and negative responses along with suggestions for modifications are discussed as follows:

- *Criticisms and Suggestions*

The major criticisms of the content structure by the students were:

- (1) Seven of the 14 students felt that the structure of the teaching content was un-systematic; for example,

When you teach, you keep on jumping here and there (in theory). I feel the structure is lacking system and integration. Perhaps it is because I am still not used to it. (S9)

- (2) Nine students said that the content covers too many concepts in one teaching unit; for example,

In the satellite unit, you mentioned too many theories in one lesson and made it seem difficult. Our background is really weak; I think you should tell us which theories you will cover before every lesson, then we can preview it. (S3)

Perhaps this kind of teaching is suitable to students with strong backgrounds but not me. My background is so poor. It is very hard to link the concepts that you taught. (S14)

- (3) Two students commented that they viewed the teaching content mismatched with the textbook; for example,

The structure is fine, but you had better write a textbook to match it. The textbook that we use cannot fit to your structure. (S7)

It would appear from the above statements, that the context embedded structure

could become more applicable if students were better prepared in physics background or if a textbook which adopts a similar structure (eg, Moore, 1998) was used.

- *Positive Opinions*

As well as the negative opinions mentioned above, some students proposed the advantages of adopting the context structure.

Three interviewees mentioned that the context structure provided links to integrate different concepts and construct a conceptual framework. For example,

I like the new structure better than the traditional one, because in high school we learnt theories linearly and never had chances to integrate concepts... From your teaching (structure), we were challenged to link different concepts. (S10)

The structure of your teaching (content) really fits my learning habits. From the structure, you provided us with the opportunity to form a “net” of links among theories. The main barrier to my high school learning in physics was the “linear” structure (of the discipline). Because the theory is organized “linearly”, it can only train us to learn to “plug-in” but not really to think. We hardly know how to apply a learnt theory to a new phenomenon. Although it (the structure of discipline) looked systematic on the surface, the structure retarded my thinking. (S3)

In order to help the students revise the content after class, the lecturer (researcher) provided a brief summary of the concepts covered at the end of each unit. The summary of the key points of the physics principles provided the names of the physics principles and a page reference in the textbook. Responses to the summary from interviewees were all positive. The students commented that the summary helped them to clarify the key points as well as link the teaching content to the textbook. For example,

We think the summary is necessary, otherwise we really have no idea about what the key points are at the end of the lessons. (S5, S6)

I don't feel that your teaching structure is loose because you always give us a summary. (S11)

There is no problem for me to revise from the textbook because you have provided the summary. (S4)

- **Modifications**

Based on the students' suggestions, ways to help alleviate the students' anxieties and make the structure more acceptable are discussed below:

- (1) Six of the 14 students recommended that the intervention teaching should spend more time to explain *why* and *how* the content will be structured at the beginning; for example,

Your structure sounds fine but needs more explanation to us in the beginning, because it is very different from what we were used to learn. (S2)

- (2) Seven students suggested that the researcher slow down the teaching pace initially; for example,

After two months of vacations, many concepts were mixed up in our mind. We need time to organize them in the beginning stage. I think you should slow down your teaching in the beginning, or many of us will find it hard to follow. (S12)

The above modifications are essential, particularly in the early stage of the intervention teaching, to help students to adjust to the transition. It is expected that when students gradually become accustomed to the new structure, greater indications of the strengths of the design should emerge.

9.2 Teaching approaches

The second major aspect of the data analysis is the students' perceptions of the teaching approaches.

Three teaching approaches which differ from traditional teaching were used in the intervention teaching, comprising:

- (1) interactive teaching,
- (2) questions before teaching, and
- (3) everyday life phenomena before theories.

The designs of these teaching approaches are described in section 7.4.

The students' responses towards each teaching approach are discussed below.

9.2.1 Interactive teaching

The first teaching approach used in the intervention was the interactive teaching.

All of the 14 interviewees noticed that the intervention teaching had increased interactions in class, and all of them preferred the interactive teaching to the traditional transmission teaching. Only two students had experienced a similar approach providing interaction in class before entering university, while the other twelve interviewees regarded the interactive teaching in intervention class as new and fresh to them. The students' perceptions of the strengths and weaknesses of the interactive teaching approach are detailed below.

- *Strengths of interactive teaching*

The students commented that the perceived strengths of the interactive teaching approach are:

- (1) All of the 14 students mentioned that the interactive teaching approach had promoted their engagement in thinking about physics concepts. This was considered to be a significant strength when compared with their high school learning experience. According to the students' responses, at high school the thinking process was usually absent, while teachers kept talking without interaction. For example,

You are very different from my high school teacher because you always give us a couple minutes to think about and discuss the concept questions. For a better learning outcome, it cannot be obtained by letting the lecturer keep "dumping" something on us as our high school teacher did. We need time for thinking, not just keeping copying notes and memorizing formulas. (S1)

The interactive way of (your) teaching promotes our thinking deeply. Not like some professors who just keep writing notes on the blackboard and keep talking. (S5)

- (2) Almost all of the students (13 of the 14) thought that the interactive teaching was beneficial to concentration retention in class; for example,

This (the intervention) is the first experience that I have had of being taught in the interactive way... Interactive teaching is more attractive than just

writing and can make us concentrate more. (S5) Yes, such as in X class, over half of our classmates fell asleep. If the teacher just keeps talking in class, students will feel sleepy. (S6)

I have an “over-active” mental illness since childhood. The problem makes me usually feel uneasy and I have difficulty concentrating for more than ten minutes sitting in class. But in your class, you provided us with many different learning activities. This can help me a lot by attracting my attention in the lesson and makes it easy to keep concentrating. (S7)

In your class, I feel it is more interactive, and I can keep concentrating, because I have something to do, not just listening... In the classes of many other subjects, I often doze, but this problem never happens in physics class. (S12)

- (3) Four of the 14 students said that the interactive teaching provided opportunities to challenge their understanding of the physics concepts and helped them identify their misconceptions; for example,

When I discussed with my partner, most of the time he asked me and I explained to him. Sometimes I can find that there are some mistakes in my understanding of the concepts. This is the advantage of (small group) discussion. (S3)

It is good that you let us answer the questions first and teach according to our answers, since you can then focus on what we are most unclear about. (S7)

- (4) Seven students commented that the interactive teaching has shifted the focus of teaching from the teacher and teaching materials to the learners and learning outcomes. For example,

Teaching should be like your teaching, which is more concerned about our learning (than your teaching), not just keeping talking on your own. The focus of the class should be the students not the teacher. (S10)

In traditional teaching, unless we are very diligent students, and spend lots of time revising after class, we won't really learn it, because we were only listening, not thinking. (S12)

- (5) Nine students were asked, in the interviews, if they felt that the lecturer was lazy using the teaching time for students to work by themselves, and all of them gave an answer of “no”, without hesitation; for example,

S7: Your teaching always gives us time to think.

Researcher: Have you ever thought that I am not committed to my teaching, because I don't keep teaching all the time (but give time for you to answer and discuss)?

S8: Not at all. It is good to let us discuss, not just about the answer, but also the reasons.

S7: The time (for thinking and discussing) is worthwhile. Whether a teacher is committed in teaching or not, depends on how much time he has spent on preparing and designing the teaching, not on talking hard in class. I believe that you have spent a lot of time preparing for your (intervention) teaching, because your teaching (style) is so different from other classes. The (focus of the) class (activity) should belong to the students not the teacher.

The intervention students' responses did not agree with some other studies or with the lecturers' opinions found from this research. In Banerjee and Vidyapati's (1997) study, they found that some students felt that they would not need the teacher anymore, since they can learn by group discussion. Also, from the lecturer interviews in this research, many lecturers emphasized their responsibility to "teach"(see section 5.4.3). Very often, they limited the meaning of the word "teach" to "talk". Their responses imply that a lecturer will not fulfill his duty if she or he does not keep teaching (transmitting) the subject content.

(6) Most interviewees (12 of the 14) admitted that the interactive teaching approach could have a negative impact upon content coverage, but they also emphasized that the teaching is beneficial to them in enhancing their understanding of the concepts, and thus they learnt more from the interactive teaching approach.

Yes, you teach less under this kind of (interactive) teaching, because you have spent time to let us think... but we understand more. (S11)

I don't think this (interactive) activity is wasting teaching time and that the pace becomes too slow. Comprehension of some physics principles is more important than content coverage. (S6)

On the surface, interactive teaching may make students feel that they have learnt less than traditional teaching. The traditional way always keeps teaching, so it can teach more. But it is just a kind of "baby-feeding". The focus should be on how much we learnt, not how much the teacher taught. (S9)

In summary, the students' perceived strengths of interactive teaching were that it (1) promotes their engagement in thinking, (2) helps concentration retention, (3) helps identify their misconceptions, (4) shifts the focus of the class from teaching to learning, (5) has no negative impact on teaching commitment, and (6) less is taught, but more is learnt.

Responses from the intervention teaching students are mostly consistent with the findings of many research articles (eg, Drew, 1990; Hake, 1998; Mackin, 1996; Mazur, 1996; McDermott, 1997).

- ***Barriers to applying interactive teaching***

Although all interviewees pointed out many strengths of the interactive teaching, the students' engagement in the class activities was not always high. Possible barriers to applying the interactive teaching were also investigated in the interviews. From the student comments in the interviews, it would appear that attitudes towards joining small group discussions are not always the same as those towards questioning the lecturer in class. The main reasons for hesitating to become involved in small group discussion were related to the learner's self-confidence. The perceived obstacles are listed below and some quotes illustrate the students' perceptions:

(1) Insufficient background

Nine of the 14 students pointed out that their high school background in physics was weak, and this made it difficult for them to answer many questions, even those looked simple. When students have no confidence in their own answer, they are less willing to discuss it with peers. For example,

Yes, sometimes I did, since two opinions should be better than one. But sometimes I was still thinking by myself when I had no answer. (S11)

The more we know, the more we will be involved in the discussion. If one had nothing in his mind, he will feel hesitant about discussing with others. (S10)

(2) Being afraid of wasting peers' time

Three of the students mentioned that although they felt it would be beneficial to discuss with peers, they categorized themselves as belonging to the low achievement group and played the role of pure receptors, making no contribution to the discussions. This perception made them feel that the discussion was a waste of their partners' time. For example,

My physics background was poor, so I often go and ask my peers questions.

But I am afraid that this will waste too much of their time. (S4)

(3) Being afraid of being blamed or teased by the lecturer or peers

Six of the 14 students said that they are afraid to expose their weakness in front of the lecturer and their classmates. They would rather leave the question unsolved than risk being put down by peers or lecturers. For example,

Most of us dare not ask the lecturer questions. We are afraid that maybe the lecturer will blame us for asking such a simple question which had already been taught. Besides, we will worry that perhaps it is only us who has the question and that we will be teased by our classmates. (S4)

(4) Lecturers could not understand students' difficulties

Seven of the 14 students felt that the lecturer can hardly understand their difficulty. They felt that it is easier to communicate with their peers than with the lecturers. For example,

Because lecturers possess such a high academic achievement, they can hardly know what/how we are. (S4) Yes, indeed. (S1, S10)

When I have questions, I would prefer to ask my classmates instead of the lecturer. Since lecturers have such a high academic background, they cannot really understand our difficulty. However, I dare to ask my friends every trivial detail because we learn it at the same time, and so they can understand more about my problems. (S3)

Yes, peers can use the words that we feel are easier to understand to explain our questions. (S1)

According to the students' responses, the high authority in academic achievement of university lecturers seems to hinder lecturers' understanding students' learning difficulties. Although the students were quite understanding, high academic achievement should not be an excuse for lecturers to be ignorant of students' learning difficulties.

- ***Ways to promote students' engagement in classroom activities***

In addition to the discussion of the students' perceived barriers in conducting the interactive teaching, this research also searched for possible ways/methods to increase the students' engagement in the classroom. The following methods may promote interactions in class.

- (1) Demonstrations: The researcher introduced two demonstrations³ in the intervention teaching. The two demonstrations were both followed by concept questions. Ten interviewees pointed out that the advantages of demonstrations are that they are attractive, visible, and convincing. For example,

The demonstration about the weights of the hourglass was attractive. Since you brought the scale to verify the answer, this can convince us about the theory explanation. (S12)

The demonstration or OHP made us feel that the phenomena were approachable. That is why we discussed those topics more actively. (S4)

- (2) Raise hands for your answers: Many concept questions in the intervention teaching were multiple choice questions, and the lecturer (researcher) went through each alternative, and the students raised hands for their choice without explaining reasons. Five students said that although they felt nervous to speak about their ideas in class, they were much more relaxed about presenting their understanding of the concepts in this way. For example,

When you asked about our answers (about the concept test), I would prefer the way of raising hands instead of calling on students. I am too shy to present my opinions in public, but on the other hand I am curious to know whether I got the right answer or not. When I picked the correct answer, I felt satisfied about my performance. (S9)

- (3) Select an appropriate level of questions: Four students commented that selecting appropriate level of questions could promote learning engagement. For example,

The selection of the questions is very important. Just a little bit higher than what we know is fine; too difficult questions will undermine our confidence. (S3)

Your (concepts) questions were always simple, and simple is good. We can therefore really learn something basic. (S9)

In order to stimulate involvement in discussion, the selection of the concept questions is crucial, especially in the area of difficulty. The questions must not be too easy or the learners will feel bored, and they must not be too difficult to undermine their confidence. From the interviewees' responses, the latter is more

³ weights of hourglass and forces on a rotating ball

harmful to learning than the former.

Concluding from the students' responses, they perceived the interactive teaching approach as more effective and appealing than the traditional lecturing. They strongly supported the teaching approach, although this was the first experience of the new teaching approach for many of them. Supportive responses from the interview students agreed with the results of earlier stages of this research that a few students have pointed out their expectations of the interactive teaching approach (see section 4.3.3).

Overcoming the existing barriers in introducing the interactive teaching approach may need more implementation time for both the lecturer to improve the teaching skills and the learners to adjust their learning habits from passive receptors to active participants in order to adapt to the new teaching approach. As a result, seven of the 14 students mentioned that the intervention teaching needs to be applied for longer and then the outcomes would be more significant.

9.2.2 Questions before teaching

A second teaching approach used in the intervention was the teaching sequence of questioning before teaching.

In the traditional university physics course, physics lecturers usually focus on introducing physics concepts and solving problems. Concept questions are either absent or appear after the related theory has been taught. To provide students with challenge to stimulate their thinking, the intervention teaching always proposed one or two questions to stimulate the students' thinking and discussion at the beginning of each lesson before introducing the theory. Details of the design and the purposes of the new teaching sequences are discussed in section 7.4.2.

- ***The advantages***

The students in the interview gave positive responses to this new teaching approach. According to the students' comments, the advantages of the new teaching approach are summarized below:

(1) Seven of the 14 students mentioned that the teaching sequence of questioning

before teaching stimulated their thinking about their understanding of physics concepts. For example,

Your teaching (approach) is more challenging, and (that can) stimulate my thinking... I believe that most of our classmates have worked really hard on the concept questions, no matter whether our answers were right or wrong, the thinking process can let us achieve something. (S10)

- (2) Six of the 14 students said that the new teaching sequence had promoted their awareness of their weakness and/or helped concentration in class. For example,

It is good to have space (time) to think in class, not always just to listen. If we had the wrong answer (in the concept test), we will concentrate more on listening to the concepts that the lecturer explains afterwards. (S12)

I think that giving us questions before telling the theory is a good idea because all the theories you taught were not new to us. The questions can remind us how much we have forgotten and clarify what we do and do not understand. (S2)

The principle for solving the question of the “falling vase” is so simple and familiar, but when I answered the question, the principle just did not appear in my mind. I think many of us have the same problem that we don’t know how to make our (understanding of physics) concepts complete. (S7)

- (3) Eight students mentioned the necessity of previewing when dealing with the questioning before teaching approach. For example,

The questions should not be so difficult. But this (questions before teaching theories) is really fresh to me. To answer those questions, preview is necessary. I think it is good to establish the learning habit of previewing, because we never previewed in high school. (S1)

I think to answer those questions, previewing before the lesson should be very helpful. I would appreciate it if you could notify us of the physics principles that will be covered in the next lesson. (S8)

The challenge of questioning before teaching seemed not to undermine the students’ confidence. On the contrary, most interviewees expressed a positive attitude to overcoming the challenge as well as awareness of deficiency of their prior physics background. They realized the importance of previewing and were prepared to fulfill the task.

- (4) Four students noted that the teaching approach guided them to a

comprehension learning approach rather than learning by rote. For example,

If you taught the theory before giving us the questions, you would provide too many clues for us. We will only need to “plug-in” instead of doing some “deep thinking” when we answer the questions. (S4)

(5) One student commented that the approach doubled the chances of learning both in answering the questions and from the lecturer’s instruction.

I like the way that you gave us questions first, then taught the theory again. This method gives us two chances to learn. (S5)

- ***The difficulty***

In addition to the supportive responses to the new approach mentioned above, two of the 14 students noted that they experienced difficulty in the early stage due to their insufficient academic background. For example,

In the beginning, I really didn’t know how to start to answer those questions. During the last two-months holiday, I had forgotten many physics concepts. But gradually, I became used to the procedure; I guess I have already got on track now. (S2)

According to physics lecturers’ views (from the interviews in phase 2), stimulating learners’ engagement in thinking and asking students to preview were regarded as difficult tasks to achieve in physics classes (see section 5.3.2). However, from the intervention students’ responses, these learning tasks are achievable if the lecturer adopts a challenging and interactive approach instead of devoting teaching time just to delivering knowledge.

In summary, the new teaching approach provides more challenge to learners as it appears to (1) promote learners’ awareness of their weakness, (2) stimulate learning engagement, and (3) encourage a deep-level learning approach while discouraging rote learning. Responses from the interview students matched the expected objectives of the researcher.

9.2.3 Everyday life phenomena before theories

A third teaching approach adopted in the intervention was phenomena before theories.

In the intervention teaching, the lecturer (researcher) always started by introducing phenomena that linked to students' everyday life experiences, and then gradually approached the embedded theory thereafter. This approach is different from the conventional teaching design in university physics, where the phenomena appear only after the introduction of the physics theory, if they are not in fact totally absent. The reasons for this modification in the intervention teaching are described in section 7.4.3.

Most of the interviewees (12 of the 14 students) expressed agreement with the approach, and no opposing opinions were raised. The students commented that the strategy of introducing everyday life examples makes physics more approachable.

For example,

(To teach physics concepts), it was nice to start from something real instead of just starting from an abstract theory. Starting from familiar phenomena made us feel physics was approachable. (S6)

I feel your teaching is easier to learn, since you always start from everyday life examples (before the theories) and that can make it easier for us to accept, and easy to understand the theories. (S4)

The students' responses matched the researcher's expectations.

9.3 Perceptions of learning

The third main aspect of the data analysis was the students' perceptions of learning.

The literature has revealed the crucial role of learners' beliefs and perceptions of learning effecting upon their learning strategies and learning outcomes (eg, Hammer, 1995b; Redish, Saul and Steinberg, 1998). Learners' perceptions of learning include what to learn, what skills will be needed, how to succeed in learning (Redish, Saul and Steinberg, 1998), as well as the perceived value of what they are learning and the beliefs in their ability (Pintrich, Marx and Boyle, 1993). Details of the learners' perceptions in relation to learning strategies and outcomes are discussed in the literature review chapter (see sections 2.2.3 and 2.2.4).

From the student interviews, the researcher also has acquired an insight into how students perceive their learning. Three aspects will be discussed:

- (1) The students' adoption of learning approaches in relation to their academic performance in physics and their attitudes towards intervention teaching;
- (2) The students' perceived learning goals: knowledge acquisition or ability development;
- (3) The students' perceived learning barriers, including language, physics background, and traditional examinations.

9.3.1 Learning approaches and links with academic performance

The first aspect of investigating students' perceptions of learning was to understand the adoption of learning approach in relation to their performance in physics.

Zajchowski and Martin (1993) studied students' learning performance in university physics in relation to their learning approach. They found that the stronger group holds an expert approach and the weaker holds a novice approach. The expert approach tends to organize under concepts first and work towards process, while those using the novice approach tend to start by searching for formulas before clarifying their concepts, and then work backwards.

According to the criterion provided by Zajchowski and Martin (1993), 11 of the 14 interview students can be distinctly categorized into either learning approach: five students adopted the novice learning approach and six adopted the expert approach⁴. Some quotes can interpret the features between different learning approaches.

It was hard to solve the problems (in the unit on satellites). After two months vacation, all the formulas were "forgotten". I was trying to pick up those formulas (from my mind) and plug-in.... Your teaching made us feel that it was more enjoyable and easier to "remember". (S11) (Novice)

⁴ The other three interviewees were not able to be grouped into either approach.

It is good (to have the Force Concept Inventory test) in the beginning (of the semester) to see how much we still remember after two months free from study. (S3) (Novice)

But, as long as you really understand the concepts, you will be able to solve those (concept) questions (in the Force Concept Inventory test). Two months vacation will not hurt your performance (in the test). (S4) (Expert)

When I work on problem solving, I need to figure out the physics concepts first. This is the most important thing; formulas are trivial. (S13) (Expert)

The results of the two groups in the tests are listed in Table 9.1.

Table 9.1 A comparison of performance and gains between the students with expert and novice approaches

Learning Approach	Concept test		problem test	
	pre-score	gain ratio (%)	pre-score	gain ratio (%)
Expert (6)	63	27%	52	4 %
Novice (5)	55	11 %	45	1 %
Δ between groups	15 %*	16%	15%*	3%

* The data is calculated by (Expert-Novice)/Novice.

The standardized tests were held during the first lesson (pre-test) and then in the 7th week of the semester (post-test). Both the concept test (Hestenes, Wells and Swackhamer, 1992) and the problem test (Hestenes and Wells, 1992) were given at the same time. The gain ratio⁵ as defined by Hake (1997) indicates the ratio of what students have learnt between the pre-test and post-test periods. Details of the tests are introduced in section 3.4.2.

Although the sample was too small to apply statistical significant verification, some implications are worth discussing. Comparing the scores of the two standardized tests of these interview students with their learning approach, there are links between academic performance and learning approach.

According to Table 9.1, it can be seen that the group with the expert approach was

⁵ Gain ratio is defined as (post score - pre score) / (100-pre score)*100%

equipped with a stronger background (as shown in the pre-scores) than the novice group, in both concept and problem types of tests. The expert learning group was about 15% above the novice learning group in both concept and problem tests in the pre-scores; this matched with the findings from Zajchowski and Martin (1993). The gaps in the background between the two groups were similar in both the concept and problem tests. However, the learning effects of the two types of tests (concept and problem) for the different learning approach groups were very different. The gain ratios of the deep learners were higher than that of the surface learners in both types of tests. However, the gaps between the two groups of learners were more significant in the concept test ($\Delta=16\%$) than in the problem test ($\Delta=3\%$). The results imply that the intervention teaching is more beneficial to the students who use the expert approach than those who use the novice approach in enhancing their physics concept without retarding their problem-solving ability.

In summary, it would appear that the students' adoption of learning strategy is related to their academic performance. The students who hold an expert learning approach are likely to have a stronger physics background than those with novice approach. Meanwhile, the intervention teaching may be beneficial to the expert approach group in academic achievement, especially in enhancing their understanding of physics concepts.

The next step is to discuss whether students with different approaches expressed different responses towards the intervention teaching.

- ***Responses to the intervention from students with different learning approaches***

During the analysis of the interview data, the researcher found that the group with an expert learning approach responds much more strongly to the intervention teaching design than the other group. More often, these students with the expert learning approach not just felt pleased to accept the new teaching style, but also expressed that many ideas of the intervention design were what they had expected. Also, they were more likely to point out the reasons for the intervention design implicated by the researcher. The following quotes illustrate the above statements.

Expert: From your teaching, I can understand more deeply than before about what you have taught. I have not just become more capable in problem solving, but also it has helped to clarify my concepts... If I could have met you earlier (in my high school), my physics background would not be so weak. (S10)

Novice: I am not sure (about improvement in my physics concepts)... My physics concepts are very weak, I think I need to spend more time "reading" it (in the textbook). (S11)

Researcher: How do you feel about the levels of the teaching content?

Expert: I feel they are not too difficult for me, and your teaching helped me a lot to integrate the physics concepts. Teaching physics should be like this. (S10)

Novice: I don't feel you are integrating concepts. In the satellite unit, I could not solve all those problems. I was trying to think about the respective formulas and plug-in. (But), all the formulas were forgotten. (S11)

- ***Teaching as an aid to promoting learning approach***

The above discussions have indicated that the learning approach strongly influenced the learning performance, and the teaching preferences of learners with different learning approaches. The importance of learning approach to the learning outcomes has been shown. Also, the effectiveness of the new teaching design has been shown to be widely varied according to the approaches adopted by the learners. An important issue emerged from the above findings, that is, whether learning approach can be changed under different teaching approaches. In other words, whether a flexible teaching approach can broaden the perspectives of the students and guide them to adjust their learning to be more flexible?

The question was investigated in the students' survey (survey 3B), and the students' responses showed that the intervention teaching had a significant achievement ($p < 0.001$) in guiding students towards holding a more flexible and deeper learning approach, when compared to other classes (see section 8.1.5).

The adjustment of the learning approach during the intervention teaching was not intentionally investigated during the student interviews. Three weeks of intervention may be too short to investigate the shift of the learning approaches with respect to each individual. The researcher expects that this issue might be explored in more depth in longer term research in the future.

In summary, the results indicated that (1) students' adoption of ^alearning approach is influential to their performance in physics, (2) the students with an expert learning approach expressed stronger preference towards the intervention teaching style than the other group, and (3) the intervention teaching seemed to have a positive impact on encouraging students to modify their learning approach.

9.3.2 Learning goals: Knowledge acquisition or ability development

The second aspect of learning highlighted in the analysis of the interviews was the students' perceptions of learning goals.

During the interviews, there were several debates among the interviewees about the objectives of small group discussion which refer to the goals of learning physics. Some students emphasized obtaining a correct answer while the others focused on the process of discussion that developed their thinking ability. A typical conversation was as follows.

Your teaching is not just to teach physics content but to show us the methods of thinking. Teaching should be like this. (S7)

Sometimes I wonder why I need to spend so much time solving those problems; they (mathematical skills) are useless for my future career. What we need is to be able to think; thinking ability is important for our whole lives. (S1)

I usually worked hard to discuss with my partners and tried to get the result, but sometimes we still could not get the right answer. (S4)

But why just care about getting the right answer? Why not think about (what we gain from) the process (of discussion)? I think that logical reasoning ability is more important to me for my future. (S1)

Indeed, thinking ability is more important than the physics itself. (S3, S4, S10)

While interviewing, the researcher was careful to avoid altering the interviewees' responses (Patton, 1990). She was pleased to see that the expected learning goals, after similar debates among interviewees, had shifted from knowledge acquisition to the development of thinking ability. The seeds of deep perspectives of learning in a small minority of students' minds seemed to spread out during the debates. As

a result, seven students agreed and one disagreed that the process of practicing thinking is more important than obtaining physics knowledge in learning university physics.

The influence of learners' perceptions of learning goals and tasks on their learning orientation has been discussed in many articles (see section 2.2.3). It would be worthwhile investigating whether the learners' perceptions about learning will diverge with respect to different styles of teaching in further research.

9.3.3 Learning barriers

A third aspect of the students' perceptions of learning was to understand what factors the students perceived to be hindrances to their learning. University physics is usually regarded as a difficult subject by students, and the prevalent problem of a high failure rate has been addressed in the literature (see section 2.1.1).

During the interviews, possible barriers that retarded students' learning were mentioned in the students' responses including (1) language, (2) physics background, and (3) traditional examinations.

(1) Language

Eleven of the 14 students pointed out that they felt it was difficult to read the English version textbook, and wished the lecturer to provide some guidance in reading textbooks; for example,

When you gave us the question on “stopping distances”, I got stuck with the symbol “ft”, and I didn't know what was meant by “reaction distance” and “breaking distance”... It would have been an easy question for us if it had been in Chinese. (S13)

The English textbook made us feel that we didn't know how to study physics after class. (S1, S2)

I feel the main difficulty in learning physics is reading the English (textbook), not the physics itself... Please give us some guidance to cope with the English barriers. (S1)

Meanwhile, six of the students argued that they spent more time in understanding

the English text than figuring out physics concepts when solving the assigned problems; for example,

Researcher: How do you feel about the assigned problems (at the end of each chapter)?

S5: I cannot understand them, if the (English) problems are too long,

S6: Since the (content of) problems is similar to that of high school (physics), I felt I have spent more time in figuring out the meaning of the problems (English) than thinking about the related physics concepts.

(For solving the assigned problems), I have spent much longer checking through the dictionary than dealing with physics (concepts)(S2).

Eight of the 14 students mentioned that lecturers tended to keep using English terminology without any explanation while teaching, which was also regarded as a prevalent problem; for example,

I feel reluctant if the lecturer keeps writing English terminology on the blackboard. Lecturers don't seem to understand our difficulty with English... In one lesson on subject X, the lecturer only wrote two Chinese words, the blackboard was full of English words and symbols... I had absolutely no idea what he was talking about. (S1)

Although most students suffered from their weaknesses in English while learning physics, no one argued against using an English version textbook for the physics course. Most of the students were willing to face the new challenge of reading English textbooks in university study, but they expected assistance from lecturers that was usually lacking.

(2) Insufficient physics background

The second of the existing barriers in learning university physics for the students was the insufficient physics background.

Among the fourteen interviewees, twelve felt that they had a poor physics background before entering university. For example,

My physics background is weak. I did not study hard in my high school. (S11)

Our physics teacher in high school was great, he designed his own handouts and taught accordingly. He is smart... But I just could not understand what

he was teaching. My (understanding of) physics concepts is not clear and lacks system. (S4)

Five students said that they had learnt nothing about physics in high school. For example,

The teacher I got in high school physics was not a good teacher. (In our class) nobody listened to what he was talking about... I could only give up physics (at that time). (Therefore), I learnt nothing (in high school physics). That is why I work really hard on university physics, I hope to improve it at university. (S10)

Although most interviewees emphasized their weakness in physics, there were no responses regarding the difficulty of the mathematics. Student perceptions imply that in their physics classes they require more development in physics concepts than in practicing mathematical skills.

Although students were not satisfied with their previous learning outcomes, the performance of these Taiwanese students was much better than that of the US students in both the concept and problem pre-tests (see section 4.5.4).

(3) Traditional examination

The third concern of the students with respect to the learning obstacles in university physics was the tool of traditional examination.

While most of the students expressed positive support for the intervention teaching style, they also realized the mismatch of the new teaching style and the traditional examination⁶. Six of the 14 students criticized the traditional examination as encouraging rote learning, which is inconsistent with the focus of intervention teaching. For example,

Your teaching is very different from other (classes), but I wonder how we can deal with the (unified) examinations... In university study, I am more concerned about really learning something than just dealing with the exams. But grades are usually the most important things to most Taiwanese students. Actually, I think university (education) should not have Mid-term and Final (Exams). University should provide us with more flexibility. Just like your teaching, which is more flexible because you have given us more space to think. (S9)

⁶ The intervention students will need to attend the unified examinations that were regarded as traditional format.

The most important strengths of your teaching are that you succeed in making us think actively. I think teaching reform should start from primary school, but we have too much pressure from the examinations. (S7)

At the same time, three of the students expressed their anxiety about the mismatch of intervention teaching and the traditional examinations that they are required to sit.

I feel that I really think hard (deeply engaged in thinking) in your class, and I really understand quite a few of the concepts. But I am worried about how the exam will appear.... It would be great if you could break the traditional examinations. ... They always need us to memorize a lot of stuff and just plug-in. (S1)

According to the students, the so-called “examinations” not only encourage rote learning such as reciting, but also discourage deep-level learning such as comparing or integrating. The research suggested that in order to promote learners to a higher-level learning outcome, traditional assessment procedures must be drastically modified.

9.4 Summary of the intervention program

After analyzing the interview data with respect to each aspect of teaching and learning in the above sections, the researcher would like to summarise the overall findings with respect to the intervention teaching. Three aspects will be discussed:

- (1) comparison of the intervention teaching and traditional teaching,
- (2) strengths and weaknesses of the intervention teaching,
- (3) suggestions for future teaching.

9.4.1 Comparison of the intervention teaching and traditional teaching

Since the interviewees when interviewed had not received any teaching in university physics other than the intervention teaching, they made comparisons between high school physics and intervention teaching.

Among the fourteen interviewees, only one student was satisfied with the teaching

style of her high school physics class in general, and she was the only interviewee who regarded the teaching of her high school as “non-traditional”. According to the students’ responses, a few features indicating the distinction between traditional and intervention teaching styles are summarised in Table 9.2.

Table 9.2 A comparison between intervention and traditional teaching according to the intervention students

	Intervention teaching	Traditional teaching experienced in high school physics
Content	Focus on concepts/ link to life (14)	Irrelevant to life (10) ⁷
	Structure of context (7)	Structure of the discipline (7)
Teaching	Interactive teaching (12)	Force-feeding (10)
Learning	Focus on learning (7)	Unaware of learning (8)
	Learning activities are variable (9)	Only copy notes in class (6)
	Engaged in thinking (14)	Limited to memorizing formulas without thinking (7)
Outcome	Teaches less, learn more (7)	Teaches much, learn less (11)
	Feel interested and concentrate in class (9)	Easy to loose concentration (12)
	Stimulates comprehensive learning (12)	Encourages rote learning (12)
	Outcome will be revealed in longer term (7)	Learning outcome is frustrating (12)

In teaching content design, the interview students noted two significant differences between intervention teaching and their prior experience in high school (traditional teaching). The intervention teaching appeared to place more emphasis on clarifying the students’ understanding of physics concepts and providing links between physics theory and everyday life experience than the traditional teaching. Also, most of the students noticed the differences of the content structure between the two teaching styles.

In the area of teaching approach, the students strongly criticised the didactic way of teaching in traditional teaching and expressed their preference for the

⁷ The numbers in the brackets indicate the number of interview students who made this statement

intervention teaching which induced more interactions in class.

In the aspect of learning, the students' responses indicated that in the intervention teaching they (1) become more aware of their learning, (2) actively engaged in the learning process, and (3) participated in a variety of learning activities in the classrooms, in contrast to the monotonous learning experience and the indifferent learning attitude in their high school physics classes.

In the learning outcomes perceived by the intervention students, they felt that the new teaching program promoted their learning interest, and encouraged a comprehensive learning approach. Although the intervention teaching appeared to teach less, they learnt more, and the teaching approach was also regarded as promising for a longer term. This positive appraisal is widely divergent from the students' negative comments about their high school physics, which appeared to be frustrating for their learning achievement.

The criticisms of the students' high school physics are similar to those of the traditional teaching in university physics investigated prior in this research through an open-ended questionnaire survey (see section 4.3.1).

The problems with traditional teaching as indicated by the interview students are surely not limited to Taiwan (eg, Holton and Horton, 1996; Linder, 1993b). In many countries, new models of teaching university physics courses have been applied and the outcomes have been evaluated by many researchers (eg, Dudley and Bold, 1996 in NZ; Sun and Lau, 1996 in HK; Redish, 1996 in the US; Wubbels and Brekelmans, 1997 in Germany). Tobias (1992) described the innovations as "revitalizing" the course. However, the researcher did not find any similar articles studying the innovations of university physics education in Taiwan. The intervention teaching in this research is probably the first trial in Taiwan.

As illustrated in Table 9.2, the intervention teaching received quite positive support in general, although much more effort and long term study in the future is required to achieve the necessary improvements. A summary of the intervention teaching's, strengths and weaknesses, are discussed below.

9.4.2 Strengths and critiques of the intervention teaching

The following summary is based on students' views of the strengths and weaknesses of the intervention teaching. Their opinions should be regarded as important references in implementation.

- *The strengths*

Most students commented that the advantages of the intervention teaching were that it:

- (1) promotes interest in learning physics,
- (2) provides links between physics theories and everyday life phenomena,
- (3) stimulates engagement in thinking,
- (4) establishes learner awareness of their weaknesses in physics, and
- (5) guides the learner to a deep and flexible learning approach.

The strengths identified by the intervention students showed that the new teaching program succeeded in enriching the students' motivational beliefs and enhancing their learning engagement rather than merely being restricted to the development of physics knowledge. It would appear that the intervention teaching had a positive impact on the students' beliefs of what and how to learn physics through the participation in classroom activities. The intervention teaching students expressed positive support of the teaching style which may have been reinforced by the fact that they shared the same learning goals as the researcher.

While strongly supporting the intervention teaching, some of students also expressed their dislike of the traditional teaching, and their expectations that the researcher would spread out the ideas of the intervention teaching design in order to benefit more students. The following quotes were made at the end of one interview, which was held one day after the researcher completed the 3-weeks intervention.

Researcher: Well! I have finished all my questions now. Do you still have any suggestions or comments?

S1: Will you keep teaching us?

Researcher: I am afraid not. From next week, your official lecturer will come to pick up the teaching.

S1: I am worried about whether he will keep your teaching style or will bring us back to the traditional style again... Education in Taiwan should adopt the teaching approach (like yours) that emphasises thinking.

S10: You should share your teaching experiences (in intervention) with more physics lecturers so that (your ideas) could be beneficial to more students.

S4: I think you (your ideas) should also influence lecturers in other subjects, (not just physics). Three weeks (in intervention) is really too short.

S1: Anyway, I think we are lucky to be selected (to be your intervention class)... I really wish you could teach us longer.

S10: Yes, to just succeed for three weeks, and then stop is really a pity.

- ***The criticism***

On the other hand, a few criticisms also emerged from the students' comments, which are summarised under the following three points:

- (1) The content covered was too wide;
- (2) The content structure was loose, and the key points were unclear, and
- (3) The teaching mismatched the assessment

The first two points are due to the modifications of the content structure, which had created a certain level of challenge to the students, especially at the beginning. Creating challenge in cognitive aspect to the students was one of the important strategies of the intervention teaching program to promote the students' awareness of their weaknesses in concept comprehension. According to the students' responses, the level of difficulty is critical to determine the outcomes of the challenge strategy.

The last criticism is that there was a mismatch of the focus between the intervention teaching and the traditional assessment orientations. The students expressed their concern about the impact of the traditional assessment as well as supporting the focus of the intervention teaching.

In conclusion, the three criticisms expressed by the students are not the weaknesses of but the existing barriers to the implementation of the intervention teaching design. Students seemed to agree with the fundamental principles of the intervention teaching design, but felt there was a need to improve the implementation skills. In order to achieve a better outcome, suggestions for future intervention teaching are discussed below.

9.4.3 Suggestions for future teaching

In order to promote the teaching outcomes, the intervention teaching design will need some modifications in implementation. According to the students' responses, suggestions are discussed as three points:

- (1) convincing the students of the need for the teaching modification,
- (2) understanding the students' situation, and
- (3) expanding the period of the intervention teaching

- ***Convincing the students of the need for the teaching modification***

The literature has revealed that the students' beliefs of what to learn and how to learn play an important role in their learning orientation and learning engagement (see section 2.2.3). When applying a new teaching style, it would be beneficial to the teaching outcomes if the lecturer tried to communicate to the students why she or he wanted to make those changes, before and during the teaching process (Bell and Gilbert, 1996, p.117). However, to minimize possible interference and find out students' genuine opinions, the researcher only gave a short introduction to the what and how of the intervention teaching in the first lesson, but very little explanation of why the change was being made. Students may have felt hesitant about expressing their criticisms of the intervention teaching if the researcher had explicitly debated the reasons for her design before the investigations. However, if the new teaching is only for the reform of teaching and not for research purposes, it should be an important task for the lecturer to put his/her effort into communicating all of the reasons for the change in order to achieve better outcomes.

- ***Understanding the students' situations***

According to the students' responses, understanding the students' prior situations, including their academic background, their perceptions of learning, major difficulties for their learning...etc., are essential for a teacher to achieve a satisfactory teaching outcome. This matches with the findings of many researchers (Donald, 1993; Jones and Osborne, 1985; Prosser, Walker and Millar, 1996).

Understanding the students' situations may not be automatically achieved by teaching processes as many lecturers may think. The responses of the physics lecturers given in this research indicated a significant mismatch between the students' and the lecturers' perceptions in many areas, e.g. learning goals, learning barriers, teaching approaches (see section 6.2). As a physics lecturer for over ten years (of traditional teaching), the researcher was surprised to learn during the intervention phase of the research that she had understood far less than she thought about the students. Without interactions in class, it is difficult to read the students' mind through traditional teaching. On the other hand, the interactive teaching method in intervention teaching proved to be an effective way to approach the students' situations. The understanding of students gained from the intervention teaching includes students' preferred teaching and learning models, concept pitfalls, learning obstacles, topics of interest... etc.

To a physics lecturer, in addition to knowledge in the subject area, all of the above information is essential to achieve a better teaching outcome (Aron, 1994; Jones, 1988; Prosser, Walker and Millar, 1996; Wubbels and Brekelmans, 1997).

- ***Expanding the period of the intervention teaching***

During the interview, while most of the students expressed their preference for the design of the intervention teaching, some of them also noted the period of implementing the intervention program was far too short to achieve a significant improvement in learning outcomes. For the new teaching design, students need time to be convinced by the teaching style, and to adjust their learning approach. Only then can the strengths of the intervention teaching gradually be revealed. Three weeks of intervention teaching was too limited to enable the researcher to investigate a significant influence on the students.

Some students in the intervention teaching expressed a desire that the intervention teaching period be extended. For example,

Your teaching should be kept longer. We finally adjusted our learning to fit this kind of teaching and started to like it, but now you want to “throw” us back (to the traditional teaching again). (S2)

Yes, I think you should teach longer, and I assure you that an even better outcome will emerge. (S1)

The author looks forward to applying the modified intervention teaching design again for one complete academic year in the near future in order to investigate the outcomes more deeply.

Chapter 10

Discussion and conclusions

The discussion and conclusions of this thesis are documented in two parts:

(I) The main findings of this research, which reflect the research questions (see section 1.2.2), under four headings: (1) understanding of the traditional course, (2) outcomes of the intervention teaching, (3) comparison of this research and the existing literature, and (4) factors influencing the outcomes of the traditional and intervention teaching.

(II) The implications and suggestions of this research, which include (1) implications and suggestions for teaching innovations, and (2) implications and suggestions for further research.

10.1 Understanding of the traditional course

Based on the discussions about the existing situations (see chapters 4, 5, 6), both strengths and weaknesses were indicated by both the lecturers and the students. Significant findings about the traditional course are summarised under three headings: (1) the strengths of both the students and the lecturers, (2) dissatisfaction with the students' learning, and (3) inappropriate perceptions.

10.1.1 The strengths of both the students and lecturers

Three strengths found in both students and lecturers in the existing situation in the traditional course.

Firstly, the incoming students possessed positive learning attitudes and high self-expectations regarding the new stage of learning at university. Most of them strongly indicated their intention of becoming informed as a result of their university learning, rather than merely passing the course and earning a degree.

Secondly, the Taiwanese students were found to have a comparatively sound background in high school physics, one which is stronger than their peers in the US. This finding is consistent with the students' responses regarding their learning barriers in university physics: the difficulty of the subject was regarded by the students as the least important factor when compared with other factors, such as learning commitments and methods, and teaching content and approach.

Thirdly, most of the lecturers appeared to be highly committed to their teaching job. Despite the many years of teaching of these physics lecturers, most of them expressed a sincere willingness to search for ways to improve their teaching, when participating in this research. The lecturers' commitment to teaching also received their students' agreement and appreciation. In spite of much criticism of the course design, the students expressed positive comments in general about their physics lecturers.

10.1.2 Dissatisfaction with the students' learning

In spite of the strengths of the incoming students in their learning attitudes as well as their academic background, the learning outcomes of this course appeared to be unsatisfactory in both cognitive and affective aspects, as summarised below.

Firstly, there was a considerable mismatch between the students' original high-expectations of their learning, and their actual learning attitudes and commitments. The majority of the students appeared to have a low learning engagement in class, a low learning commitment outside of the classroom, and they tended to adopt a superficial learning strategy (see section 4.5.2). The teaching of the university physics course was found to deteriorate significantly, rather than enhance, the students' original positive learning attitudes.

Secondly, the students expressed strong criticism of the course overall. The students' overall negative perceptions of the course were particularly significant in their responses to the open-ended questions. The major criticisms of the students included the fast pace, the irrelevance of the content selection, the monotony of the teaching approach, and that the lectures were boring.

Finally, with the low engaged learners and the negative perceptions of the course, it is not surprising to find that the students' academic achievement in the university physics course is far from satisfactory.

10.1.3 Inappropriate perceptions

Another weakness of the traditional university physics course in Taiwan was found to be not only in the students' learning but also in the inappropriate perceptions of both the students and the lecturers.

Firstly, both of the two groups appeared to possess a transmission view of learning. They expressed more concerns about the content selection than about the teaching approach, which indicates that what to teach is seen as more important than how to teach to both students and lecturers. Meanwhile, both groups seemed to regard teaching performance and learning outcomes as two independent events, since they both acknowledged the poor learning outcomes while expressing satisfaction with the fulfilment of the teaching responsibility. Furthermore, considerations of promoting learning interest and motivation were regarded as subsidiary or even conflicting with the maintenance of the course quality.

Secondly, both the students and the lecturers expressed little criticism of the didactic teaching approach. Although none of them denied that a more interactive teaching approach might be beneficial to promote learning engagement, they regarded a regular adoption of this new teaching approach as practically unfeasible. The traditional didactic teaching approach was regarded as normal in university physics classes.

Thirdly, despite the long teaching experience of most of the lecturers, the physics lecturers' understanding of their students appeared to be superficial, or even divergent from the students' "actual" situations as found in this research. For example: (1) The lecturers over-emphasised the difficulty of the course and underplayed the students' emotional barriers, mainly due to the course design, when discussing the learning barriers. This misunderstanding has led to an incorrect teaching strategy, decreasing the learning outcomes. (2) Lecturers were

not aware of their students' original positive learning attitudes, and thus failed to take advantage of this critical strength to promote learning. (3) When dealing with the possibility of adopting an interactive teaching approach, lecturers emphasised the restrictions of the Asian students' conservative attitudes, which however, appeared to be insignificant in the intervention teaching.

In summary, the lack of awareness of the strengths of the incoming students and inappropriate perceptions of teaching and learning resulted in poor learning in both affective and cognitive outcomes.

10.2 Outcomes of the intervention teaching

In contrast to the negative findings relating to traditional teaching, the evaluation of the intervention teaching showed promising results of attempts to improve teaching and learning outcomes.

Firstly, the intervention program significantly improved the students' perceptions of the course overall, which included (1) interest, (2) satisfaction, (3) enjoyment, and (4) achievement.

Secondly, the program promoted the students' engagement in learning physics in class, including (1) willingness to attend, (2) listening to the lecture, (3) participating in discussion. The program also improved their learning commitments out of class, including (1) study hours, and (2) adoption of a comprehensive learning approach. The students' learning engagement was particularly significant in adopting deeper-level learning approaches such as thinking and discussion (see section 8.3.4). The program shifted the focus of the class from the lecturers' teaching to the students' learning. In the intervention class, the students were required to change from passive receptors to active participants, and the lecturer shifted from a solo performer to a learning mediator. Therefore, this program "cured" the students' dozing as well as the lecturers' sore throat at the same time!

Thirdly, the program enriched the students' perceptions of learning. Although a

few students in the intervention class acknowledged more difficulty with the course than their peers in the traditional classes, the program did not undermine their confidence, but rather, enhanced it. The feeling of difficulty expressed by the minority of intervention students referred mainly to the lack of a systematic introduction of physics theories, as well as the reduction in the mathematical derivations. However, due to the teaching design which aimed to create more challenge for the students, the intervention students expressed more awareness of their learning, including the weaknesses of their prior concepts, the complexity of learning, and the necessity of thinking and discussing in class.

Fourthly, when the intervention students expressed their appreciation of the intervention design, they also expressed strong criticisms of the traditional teaching approach and the traditional assessment orientation, which were not addressed to such an extent by the traditional group.

Fifthly, the outcomes of the intervention program were particularly beneficial in reducing the percentage of high-risk students, ie, the students who are likely to be failed in their final grades. According to the indicators of low study hours, attendance intentions, minimum effort to pass, and feelings of learning nothing from the class, the intervention students were shown to be significantly less at risk than the students in the traditional classes.

Finally, however, there is no evidence to show that the intervention teaching resulted in any improvement in the students' academic performance, according to the traditional assessment tools. With the significant improvement in both attitudes with respect to physics classes and perceptions of learning physics, an improvement in academic performance might be anticipated if the program was extended over a longer period. Meanwhile, the traditional assessment design and techniques are perhaps problematic in terms of not assessing the goals of the course.

It should be noted here that academic performance in physics is certainly not the only goal of the course. Development of students with a more preferable attitude toward learning physics, and development of students' perspectives of their roles

in learning physics are also crucial considerations of the learning outcomes. These two major learning outcomes found in the intervention program, which are critical to life-long learning, were themselves major goals of the university physics course.

10.3 Comparison of this research and the literature

Comparing the results of this research with the literature, several consistencies as well as some new findings are summarised below.

The findings in this research which were consistent with the literature include:

Firstly, the problems of poor academic performance found in the traditional teaching, were consistent with the problems identified in the literature on university physics education. A number of studies reported the prevalent problems of high failure rates (eg, Rowell, Dawson and Pollard, 1993; Tobias and Hake, 1988) and the limited gains of the students in standardised tests (eg, Hake, 1997). This research applied only standardised tests to the subjects, both in physics concept and traditional problem-solving, and obtained low results similar to those of other studies.

Secondly, the negative affective learning outcomes found in traditional classes in this research were consistent with some other research programs in university physics (eg, Hammer, 1995b Redish, Saul and Steinberg, 1998). However, this research found that the deterioration of the students' learning attitudes was surprisingly significant within a short period of the semester commencing (three weeks), which is even more shocking than the problems with their academic performance.

The literature in university physics education tends to focus more on evaluating students' academic achievement than the transition of their learning attitudes. The findings of this research raised the issue of students' affective learning outcomes in learning university physics, and suggested more concern with students' learning attitudes and affective responses towards the course, when attempting to

improve learning.

Thirdly, in agreement with the literature in general science education, this research also revealed the links between affective and cognitive learning outcomes (eg, Rennie and Punch, 1991). Students' preferable attitudes towards physics and towards learning physics in their classes appeared to be crucial to obtaining a satisfactory academic performance (see section 4.2.4).

On the other hand, several findings of this research which were divergent from, or absent from the literature, are discussed below.

Firstly, the original positive learning attitudes revealed by this study (see section 4.5.1) were not found in the literature. On the contrary, the literature emphasised the students' passive attitudes in the process of learning university physics (eg, Hammer, 1995b; Redish, Saul and Steinberg, 1998; White *et al.*, 1995). This research found that the students' original positive learning attitudes may have greatly contributed to the significant outcomes of the intervention teaching, and could be greatly developed to promote learning. On the other hand, the original positive learning attitudes in contrast to the prevalent passive attitudes towards learning (see section 4.5.2), both found in this study, indicated significant deterioration in students' learning motivations, and encompass a sign of warning to physics educators at university level.

Secondly, this research found that the Taiwanese students' high school physics background was relatively sound (see section 4.5.4), and the difficulty of the subject was not the major concern of the students when learning university physics (see section 4.5.3). This finding is in opposition to most of the western studies in this area, which usually note that the weak background of the incoming students is a major barrier to learning university physics (eg, Kurz, 1997 in Germany; Redish, 1996 in US). Owing to this understanding, the intervention program adopted a teaching strategy of creating more challenge for the students cognitively, which was shown to be beneficial to the outcomes. The success of the challenge strategy may be not only based on the students' sound physics background but also rely on their original high learning motivations. Reflecting on

Baird and Penna's (1996) study, challenge teaching cannot occur without learner motivation. High learning motivation and manageable cognitive demand are both essentialities for achieving successful challenge teaching.

The last finding of this study, which is not usually found in the literature, was the comparison of the physics lecturers' and the students' opinions regarding the teaching and learning of the university physics course. Most of the studies tended to limit their investigations either to the students' or the lecturers' perspectives (eg, Prosser, Walker and Millar, 1996; White *et al.*, 1995). A mismatch was found between the lecturers' and the students' opinions regarding the course design, as well as a lack of understanding of their students' situations on the part of the lecturers, despite their long years of teaching experience. The mismatch in opinions between the two groups was mainly in the area of content design, such as introducing life phenomena or mathematical derivations, content coverage, etc (see section 4.1.3). The insufficient understanding of the lecturers was mainly in the area of their students' strengths, which included their original learning attitudes and physics background. These two implicit strengths have the potential to be developed in order to greatly benefit and improve the existing poor learning outcomes, but in fact, they were not even noticed by the lecturers.

During the research process, the investigation of the lecturers' views seemed to promote the lecturers' awareness of the issues related to the course design, and indirectly facilitate a certain degree of modification to their teaching content design which appeared to bring it closer to the students' preferences (see section 5.2.4). The procedure of investigating the lecturers' perspectives not only obtained an understanding of their points of views, but also influenced their perceptions of teaching and learning as well as their teaching in practice. The latter two achievements were actually beyond the researcher's expectations when designing this research. In other words, the research process investigating the lecturers' points of view seemed to have resulted in the lecturers reflecting on their current teaching and their students' learning.

In summary, the findings of this research in the context of an Asian country were mostly either consistent with the western studies or not usually found in the

literature. It is perhaps surprising to see that there were practically no significant differences found between the two systems, except the students' academic background.

10.4 Reasons for the outcomes of the two teaching formats

This research described the problems of the traditional teaching in contrast to the outcomes of the intervention teaching program. In this section, an attempt to search for possible reasons for the failure and success of the two types of teaching design is made, based on the data analysis.

10.4.1 Main reasons for the poor learning outcomes

Both the students and the lecturers contributed to the poor learning outcomes of the traditional course. These factors included:

- (1) learners' lack of awareness and self-management,
- (2) teaching and learning dominated by a transmission of knowledge view, and
- (3) assessment emphasising factual recall.

With respect to the students, the problems may be mainly related to their perceptions and attitudes. The original positive learning attitudes seemed not to benefit their actual learning at all through traditional teaching. The students in the traditional classes appeared to be unaware of their learning, lacked self-management, and were dependent on lecturers/teaching in contrast to the students in the intervention teaching. The latter expressed a deeper insight into and stronger awareness of their learning. Indicators of the intervention students' awareness of their learning included an awareness of (1) the incompleteness/inappropriateness of their prior understanding of physics concepts (see section 9.2.4), (2) the complexity of establishing a thorough understanding of physics concepts (see section 9.1.1), (3) the necessity for participating in learning in class (see section 9.2.1), (4) the need to preview (see section 9.2.2), and (5) the

longer study hour out of class (see section 8.1.5).

The first three ideas identified by the intervention students are in fact key notions of a personal constructivist view of learning (eg, Osborne and Freyberg, 1985), which was part of the theoretical basis of the design of the intervention program. Although the researcher did not attempt to explain explicitly the reasons for the new teaching design, the students seemed to see the reasons and appreciated the design. The findings implied that students' perceptions of learning and learning orientations can be influenced by the teaching format, which is in accordance with the notion of the sociocultural view of learning (eg, O'Loughlin, 1992; Salomon and Perkins, 1998). It was suggested that while learning in the classroom, students may not only develop their subject knowledge, but may also reconstruct their beliefs of the goals of the course (what to learn) and effective learning approaches (how to learn) (Hammer, 1995b).

With respect to the lecturers, the effort and commitment that they put into their teaching may in fact do more harm than good to their students' learning. Due to the lecturers' superficial view of the learning process, and misunderstandings of their students' situation, inappropriate teaching strategies were adopted. The lecturers' superficial perspectives of viewing teaching and learning revealed in this research include: (1) Didactic teaching is normal, and stimulating students' participation is auxiliary to improving learning (see section 5.4.1). (2) Teaching tasks are limited to transmitting information, and the dissatisfied learning outcomes seem not to challenge their beliefs in the fulfilment of their teaching responsibility (see section 5.4.3). (3) With respect to the ways of improving their teaching, the lecturers focused on the issue of content selection rather than other issues, such as the goals of the course, which teaching approach to use, and assessment orientations (see section 5.4.4).

All of the above responses supported the arguments of this thesis that physics lecturers commonly hold a behaviourist commitment of viewing learning (see section 2.3.1). The physics lecturers' opinions indicated that they over-simplified the learning process, and thus limited their teaching tasks to articulately presenting information. In agreement with the literature, this research found that

lecturers' perceptions of teaching and learning are influential on their beliefs as to the role of a physics lecturer, and hence the teaching approaches they adopt (eg, Wubbels and Brekelmans, 1997; Hammer, 1995b). The behaviourist perspectives of teaching and learning held by physics lecturers can be a primary reason for poor learning outcomes (Hammer, 1996; Redish, 1994).

At the same time, the literature has addressed links of the teaching style to the students' perceptions of their learning and their learning and strategies (eg, Trigwell and Prosser, 1991; Roth and Roychoudhury, 1994). These relationships were also found in this research. The links between the inappropriate teaching strategies and the negative effects found in this research were mostly consistent with the notions in the literature. These were: (1) The over-coverage of the content, the unreasonable teaching pace, and the assessment emphasis on fact recalling which may encourage the students' adoption of rote learning (Pintrich, Marx and Boyle, 1993; Entwistle and Ramsden, 1983). (2) The fact that the content design appeared to be similar to high school physics may have resulted in feelings of boredom and repetition, which may reduce the students' awareness of the incompleteness in their prior concepts. (3) The content selection was mainly decontextualised and appeared to be irrelevant to everyday life, which may fail to indicate the value of the course, and thus deteriorate the students' learning motivation (Hipkins and Arcus, 1997; Jones and Kirk, 1990). (4) The teaching strategy to reduce the difficulty of the course for the students may have caused the students to under-estimate the amount of effort they are required to put into learning, to feel bored, and/or even to look down on the course. The students' responses of insufficient difficulty in physics as found in this research are also reported by Baird and Penna (1996). They referred to it as the teachers' "sin of commission" yielding to the unmotivated students. However, insufficient difficulty has been found to adversely influence the learning motivations in this research. (5) The didactic teaching methods may reinforce the students' beliefs in the transmission view of learning, endorse their passive learning habits in class, fail to activate the participation of the students in classroom activity, and thus contribute to poor academic achievement (Roth and Roychoudhury, 1994).

Overall, the lecturers' superficial perspectives of viewing teaching and learning may be a fundamental cause of the above inappropriate teaching design, which may contribute to the deterioration of the students' learning motivation, reinforce the students' superficial perceptions of learning physics, and result in the poor learning outcomes.

10.4.2 Strategies benefiting learning outcomes

On the other hand, strategies adopted in the intervention teaching, which may also have positive impacts on the students' motivation as well as their perceptions of learning, contributed to the promising outcomes. The links between these teaching strategies and learning outcomes are suggested below:

- ***Providing intellectual challenge***

The teaching strategy aimed to provide intellectual challenge through teaching sequence of questioning before teaching, and the content structure of theory embedded in context. Without providing the clues to the corresponding theory, the questions become very challenging for the students, although those phenomena are easily seen in everyday life. The results showed that this strategy was critical to the learning outcomes of the intervention teaching program, including (1) encouraging a comprehensive learning approach, (2) raising awareness of the incompleteness of the students' prior knowledge in physics, (3) avoiding feelings of boredom, and (4) promote students' learning commitment (see section 9.2.2). In agreement with the literature, providing intellectual challenge is found to be beneficial to the improvement of learners' learning attitudes (Baird and Penna, 1996).

- ***Context-rich questions***

The literature has highlighted the role of context in learning. The notion of situated-cognition states that concepts and thinking are contextualised, and the appropriation of concepts is delimited by the conditions of the given context (Hennessy, 1993; Linder, 1993). Meanwhile, from a social constructivist view, meanings of the words are determined by the corresponding social setting;

learners take cue from the specific society to construct their concepts (Driver *et al.*, 1994; O'Loughlin, 1992). Therefore, giving consideration to context in teaching is not just for attracting students' attention, but for cognitive reasons as well (Bell B., 1993, p.28-29). Context, both of the question and of the learning society, is essential for learners to clarify their understanding of the concepts of the questions (Hipkins and Arcus, 1997), and students cannot deal with the question, unless they already have some knowledge about the context of the question (Linder, 1993; Stinner, 1995).

This research found that the context-rich questions helped the physics theories to become more visible, approachable, and meaningful for the students (see sections 9.2.3 and 9.1.2), which is consistent with the literature (eg, Jones, 1988). Other advantages identified by the students were that the novelty of the questions induced learners' curiosity, induced more awareness of the students' incompleteness of their prior concepts, and stimulated their learning engagement in class (see section 9.2.2).

- ***Time for thinking and discussion***

A third strategy for improving learning outcomes was that the intervention students highly praised the time for thinking and discussion in class (see section 9.2.1). The intervention teaching allowed about half of the teaching time to be for the students' thinking and discussion. According to the students' responses, this strategy (1) helps retain learners' attention, (2) promotes learning engagement in learning in the classroom, (3) fosters the learners' awareness of their learning, and (4) encourages deep-level learning approaches (see sections 9.2.1 and 8.2.3). While students pointed out these advantages, they also noted the complexity of learning physics.

These responses from the intervention were consistent with the main arguments of a personal constructivist view (eg, Osborne and Freyberg, 1985; Posner, Strike, Hewson and Gertzog, 1982). The central themes of a personal constructivist view of learning are (1) to highlight the complexity of the learning process and presenting a challenge to the traditional, transmission view of teaching (eg,

Osborne, 1984; Linder and Erickson, 1989), (2) to address the need for learners to participate in the learning process (eg, Osborne and Freyberg, 1985), and (3) to highlight the needs of learners to engage in a deep-level learning approach, and to be persistent in confronting difficulty, in order to achieve conceptual development (Bell B., 1993; Posner, Strike, Hewson and Gertzog, 1982). Details of a personal constructivist view of learning were discussed in section 2.3.2.

The intervention students also give positive feedback on the small group discussions conducted in the intervention teaching, which supported the notions of the literature regarding social practice. Responses of the intervention students included (1) through the interactions in the small group discussions, learners can facilitate each others engagement in thinking about physics, (2) students can sometimes better understand the meanings of peers' words than those of their lecturers, and (3) it is more comfortable to discuss with peers than with the lecturer due to the lecturer's authority (see section 9.2.1). The students' responses supported the thesis that in addition to individual cognitive engagement, participating in social practices such as group discussion is also beneficial to learning outcomes (see section 2.4.2).

The above assertion is in accordance with the literature regarding social learning, including: (1) Social learning and individual learning are mediated /complementary to each other (eg, Bell and Gilbert, 1996; Salomon and Perkins, 1998). (2) Meanings of words are not fixed and objective from human activities, but rather, they are determined by social, historical and cultural contexts. While learning, people need to negotiate and share the meanings of the words to construct their own understandings of the concepts (Hennessy, 1993; Lemke, 1990; Roth, McRobbie, Lucas and Boutonne, 1997). (3) The status of the speaker can influence the meaning and the power to the listeners: notions of power are related to the process of meaning construction (O'Loughlin, 1992). Details of a sociocultural view of learning are presented in section 2.3.3.

- ***Golden stage at commencement***

Another strategy of the intervention design may benefit to the outcomes was that

the program was implemented at commencement. The students' original positive learning attitudes may have contributed to the outcomes of the intervention teaching, and the program may have enhanced the incoming students' positive learning attitudes. Therefore, the strength of the learning attitudes and the teaching design may have constituted a productive cycle in the intervention teaching.

- ***Reduce lecturer's authority and provide choice for learning***

The last strategy may promote the outcomes of the program was that the researcher intentionally reduced the authority of the lecturer and provided choice for learning including (1) lowering the status of the assessment, (2) avoiding call-on, ie, forcing students to answer questions in public, but providing opportunities for students to express their opinions voluntarily, (3) providing students with optional assignments. This strategy was shown to provide a more supportive and flexible learning environment for the students, and thus, to promote learning interest, and encourage autonomy and adoption of deep-level learning strategies, which is consistent with the findings of many studies in higher education (eg, Trigwell and Prosser, 1991).

10.5 Implications and suggestions

The above discussions have summarised the findings arising from the two different teaching designs: traditional and intervention. However, the completion of this research is not the end of the story. The positive results received from the intervention program do not imply that the researcher has solved the problems of the existing university physics education. Three points are discussed as the closing comments of this thesis.

Firstly, the delimitation and limitations of this research may result in an over-optimistic impression of the way to improve teaching and learning. The positive results for the intervention students may deteriorate when the teaching context is altered (Dunkin, 1983). Secondly, the significance of this research can be

recognised only when the key arguments of this thesis can be implemented in the classroom by physics lecturers. Some further discussions and suggestions may help to eliminate physics lecturers' hesitations to modify the teaching format that have existed for such a long time. Thirdly, suggestions for further research are offered.

These three points: (1) the delimitation and limitations of this research, (2) the implementation of the research findings in teaching, and (3) suggestions for further research, are discussed as follows.

10.5.1 Delimitation and limitations of this research

The restrictions of the teaching environment and practical considerations of the researcher's situation limited the findings of this research. Since the students' responses may be altered with respect to different contexts, the findings of this research may not be able to be applied to all classrooms. Therefore, the findings of this research, particularly the evaluation of the intervention teaching program, may need to be recommended to physics lecturers with some caution. Considerations of the particular teaching and learning contexts in the intervention program are discussed below.

Firstly, the intervention teaching was taught by the researcher with a status of "researcher", while in classrooms students are normally taught by "lecturers". Regarding the quality and effectiveness of their teaching design and performance, a researcher in Taiwan may possess higher authority than a lecturer according to the researcher's experience in teaching the intervention program. Meanwhile, teaching innovations have been become well-known and promising events with the Taiwanese public for solving the existing problems of the whole education system in recent years. Since the intervention teaching was classified under the title of research in teaching innovation, it may have given the intervention students a prior impression of "advanced" and "better". The title of the intervention program may have helped convince the students to appreciate the intervention design at the first stage. Reflecting on the sociocultural influence of learning, the status of the speaker is critical in challenging the listeners'

interpretations. This is known as the issue of power (O'Loughlin, 1992). Therefore, without the status of researcher and the title of a research program, when lecturers apply a similar teaching approach to the intervention program, which appears to be very different from the traditional approach, they may confront more difficulty in convincing the students to accept this new teaching style, and the students' agreement with and support of the change is essential for a continuing teaching modification.

Secondly, the intervention program was short - three weeks only, and there is a lack of continuing investigation into the students' opinions. The intervention students may have still felt fresh and curious about the new teaching style, and thus gave positive responses when evaluating the program. It is suggested that there is a need to examine the students' opinions further, as to whether the positive responses from the intervention students were due to a genuine feeling of better teaching and learning, or simply because it was a new and fresh experience for them.

Thirdly, the intervention teaching did not just change the method and content of teaching, but also implied a change of (1) the ways of learning in class, (2) the shift of the roles of both teachers and students, and even (3) the criteria of achievement. In other words, the intervention teaching implied a different perspective of what to learn, how to learn, and the roles as learners, from the traditional teaching format. For example, the intervention teaching emphasised the students' participation in classroom activities, shifting the students from passive receptors to active participants/contributors, emphasising the close relationship between life phenomena and the physics theories, highlighting the learning process as part of the goals of the course in addition to obtaining the answer... etc. All these modifications will need a corresponding assessment policy to facilitate the learners' shift from traditional perspectives to the new ones (Boud, 1990).

However, as explained in section 7.1.2, the unified examination (in its traditional form) still existed at Feng-chia University. The traditional form of assessment emphasises (1) mathematical derivation, (2) recalling information, (3) receiving a precise and unique "right" answer, and (4) is abstracted from the real world, and

everyday life. This means that there is a major mismatch between the assessment and the intervention teaching design. Yielding to the restrictions of the system, the intervention program intentionally reduced the role of assessment during teaching. However, a few intervention students actually expressed their concerns about dealing with the mismatch. If the intervention program had existed for longer, in the time building up to the mid-term examination, the students' hesitations regarding this mismatch were likely to have increased significantly and may have lead to a change in their attitudes towards the new teaching design. The power of the assessment system on the students' attitudes towards the new teaching design is expected to be stronger and stronger as the semester progresses. The mismatch between the traditional assessment and the new teaching design might have had a major impact on the success of the intervention program if the program had lasted longer. The literature has pointed out the crucial role of assessment-orientation in determining students' perceptions of learning objectives and learning approaches (Kember, Jamieson, Pomfret and Wong, 1995; Tynjala, 1998). Meanwhile, the assessment policy and learning objectives may influence the students' judgement of the value of the course and determine their learning motivations and strategies (Pintrich, Marx and Boyle, 1993). Therefore, it is suggested that modification of teaching design needs to be accompanied by a consistent assessment policy in order to achieve an optimal learning outcome.

Fourthly, in order to stimulate the students' willingness to participate in classroom activities, learners' motivations and the classroom atmosphere are important. For this consideration, the approachable character of the instructor as well as the cultivation of friendly classroom atmosphere is required. However, while a lecturer attempts to be more friendly and understanding, he/she may have more difficulty with classroom management. Several problems could occur, such as, skipping class, skipping assignments, and/or classroom disorder. Furthermore, once the problems of classroom management becomes significant, the lecturer may appear to have lost control of the students, which may result in the students looking down on the lecturer and may even lead to disagreement with the new teaching design. Although the problem of classroom management was not found in the intervention teaching, it should be noted that there is a possible side-effect.

A three week program may be too short for the students to become familiar with the lecturer's characteristics. It will be worthwhile examining whether the approachability of the lecturer and friendly relationship between the lecturer and his/her students can be maintained along with a well-managed classroom.

Finally, trying to adopt a new teaching design is more challenging and difficult for the lecturer than adhering to the traditional approach (Bell and Gilbert, 1996, p.112; Mohamed, 1994, p.152-157). The difficulties in implementing the design may reduce the confidence of lecturer, and/or result in making mistakes in front of the students. As discussed in section 4.4.1, a solid academic background was perceived as an important feature of being a good physics lecturers by the students. The difficulty of using a new teaching may result in the impression of the lecturer being a "novice/poor teacher", and "dissatisfied with teaching". Implementing a new teaching design requires constant trials and a series of modifications mainly according to the students' responses. There is no unique formula for all physics lecturers. Therefore, the change process is flexible and highly uncertain. This uncertainty may result in more difficulties in teaching. In the mean time, the new teaching style is usually in a more open-format than the traditional didactic teaching. The questions used in intervention teaching are usually more complex than those idealised questions found in traditional textbooks. The students may give a variety of answers as well as ask further questions in class. All these factors may greatly increase the difficulty of teaching and challenge the "precision" of the lecture.

In summary, when attempting to change the existing teaching system, lecturers may face more challenges than those experienced by the researcher as reported in this thesis. The difference in the status of the lecturer, the potential impact of the mismatch between the traditional assessment and the new teaching, possible conflict between having friendly classroom atmosphere and maintaining good classroom management, and the increased difficulty of teaching may lead to impressions of the lecturer being a poor teacher. All of these factors may have a negative impact on the students' beliefs about their learning and perceptions of the new teaching design. The students' understanding of and agreement with the

change in teaching play a crucial role in process of improvement (Bell and Gilbert, 1996, p.117).

10.5.2 Implementation of those research findings in teaching

In order to implement the outcomes of this intervention program in real classrooms, the physics lecturers' willingness to change is critical in the first stage. The findings of this research, both in traditional and intervention classes, may provide information that will convince other physics lecturers that a change of an approach is required.

- ***High threshold, high power of the interactive teaching approach***

This research has highlighted the teaching task of encouraging students' intellectual engagement and participation in class activity, ie, thinking and discussion, in order to improve learning outcomes. However, it appears to be not an easy task to fulfil. According to the lecturers' responses, many of them had experienced unsuccessful results when attempting to promote interaction in their classes, and thus their willingness to continue their attempts to modify the didactic teaching format was undermined. Although the task is difficult to achieve, the intervention teaching program showed that the existing barriers are surmountable. Once the students have taken responsibility for their learning and have become active participants in class activities, the learning outcomes of the interactive teaching approach are expected to be very powerful. The outcomes as expressed by the students were in fact much more significant than the researcher's original expectations when designing the program.

According to the literature (eg, Bell and Gilbert, 1996, p.70-91; Claxton, 1989; Cottle and Hart, 1996; Banerjee and Vidyapati, 1997), suggestions to lecturers to successfully modify the traditional didactic teaching to a more student-centered teaching format include:

- (1) convincing the students of the reasons for the modifications at the beginning, and helping students monitor their own progress during the learning process.

- (2) realising the problems of the existing teaching and the needs to change.
- (3) being sincerely committed to, insisting on modifying the traditional teaching approach, and being willing to keep adjusting their teaching according to the students' responses. Students' attitudes and responses are critical to the pace of change.
- (4) experiencing "better learning", which is crucial to reinforcing the two groups a continued commitment to the ways of improvement in teaching and learning. The so-called "better learning" implies not only better academic performance, but forms a wider perspective, which includes greater enjoyment, social cooperation, ownership, confidence and motivation.

- ***Nothing can be worse without innovation***

One possible obstacle in the attempt to implement teaching innovations may be concern about making the outcomes even worse than the existing situation, due to the innovations. However, the findings of this research showed that the outcomes of the traditional teaching appeared to be so depressed that actually it would be highly unlikely that any innovations could worsen the outcomes further. Based on the quantitative analysis in chapter 4, the disappointed learning outcomes included:

- (1) a drastic reduction in willingness to attend: Potential class-skippers increased from 0.5% to 12% during the first three weeks,
- (2) a significant proportion of students with low learning commitment: 37% of the students study no more than 1hr/wk,
- (3) a prevalent adoption of a superficial learning approach: 79% of the students crammed for the examinations,
- (4) significantly negative comments about the course: Responses about the weaknesses were over three times those of the strengths,
- (5) poor academic achievement: On average the students learnt as little as 5-15%

of the teaching content.

These frustrating findings deliver a signal of warning for the need for innovation. Meanwhile, they imply that the existing teaching is more destructive than constructive for learning outcomes, and therefore there is actually nothing much to be lost when trying to modify the current teaching design.

- ***Develop lecturers' perceptions, not provide formulas***

Although the intervention program received significantly positive appraisal from the students, this does not mean that all physics lecturers in Taiwan should and will be willing to follow the same teaching design as this intervention. In order to facilitate the physics lecturers to improve their teaching, the findings of this research can contribute to the development of the lecturers' perceptions of teaching and learning rather than provide formulas for the lecturers to "cure" the existing problems in the conventional teaching. Before the lecturers put modifications into action, they need to be convinced of the reasons for the modifications. Meanwhile, this research has indicated a clue that once a lecturer has realised the needs for or experienced success with a teaching design different from the traditional approach, it is in fact hard to prevent them from implementing further teaching innovations (see section 8.3.6).

The researcher would expect to broaden other lecturers' perceptions in four areas, as a result of this research:

Firstly, this research expects to promote an awareness of the students' opinions, and helps the lecturers achieve a better understanding of their students, particularly in their preferences of the course design and perceptions of learning barriers.

Secondly, this research broadens the scope of viewing the goals of the course and the achievement of their students. The goals of the course should include development of learning ability and learning attitudes, in addition to knowledge accumulation. Meanwhile, this research indicates the need to reconsider the teaching design and assessment policy in order to match the goals of the course.

Thirdly, a research-based investigation of the learning outcomes may provide a deeper and wider understanding of the multiple-achievements of different teaching approaches. The poor outcomes of traditional teaching, both in cognitive and affective areas, in contrast to the improvement in intervention teaching may promote the lecturers' awareness of the existing problems, and also provide hints of possible solutions.

Fourthly, the poor results of the students' academic achievement highlight the complexity of learning, which may challenge the superficial perceptions of learning possessed by many physics lecturers. This information may help lecturers realise the essentiality of activating learners' participation in class, and promote lecturers' awareness of learners' affective considerations.

It was found that most lecturers emphasised the existing external restrictions, such as time limitations, learners' academic backgrounds, and teaching resources, as the main barriers to attempts of improve current teaching. However, the intervention teaching showed that these external restrictions are surmountable. The internal barriers of the lecturers' perceptions of teaching and learning may be more persistent, and be an important barrier which needs to be surmounted.

In summary, this research provides information for lecturers about (1) the need for a change, to revitalise the stagnation of current teaching, (2) possible ways of and reasons for modifying current teaching design, and (3) the need for a wider view of teaching with the hope of broadening their perspectives as to their role as physics lecturers.

10.5.3 Sociocultural considerations of physics lecturers' attitudes towards this thesis

Whether these research findings can influence physics lecturers, depends not only on how significant the research data were, but also on how they perceive the education research, the research methodology, and the data provider (the researcher). This issue is known as a sociocultural influence (O'Loughlin, 1992). If the lecturers have a positive perception of this research, then it is likely that it

will encourage them to reflect on their teaching, be aware of the existing problems, comprehend the main issues regarding improving teaching, be willing to be innovative, and be persistent when confronting difficulties.

The physics lecturers' attitudes towards education research were found to be passive in this research (see section 5.6.1), which was also noted in the literature (Hammer, 1996). While the physics lecturers expressed high commitment to improving teaching, assistance from educational research was not expected. Many physicists may under-value the achievement of educational research, when compared to that of physics (Hammer, 1996). This implies that the education research may have inherent barriers to persuading physics lecturers. Meanwhile, due to their research experience, physics lecturers may tend to have more faith in the data from strictly controlled experiments rather than those from a more flexible setting in educational research. The reliability and validity of self-report data may also be questioned by physicists. The current tendency of the methodology in education research: interpretative and qualitative, seems to be in conflict with physicists' empirical commitments of doing research. Therefore, the mismatch between the research methodologies of physics and educational research may negatively influence physicists' attitudes towards the arguments of education research. Furthermore, consideration of the researcher's title: "lecturer", which is the lowest teaching position in a Taiwanese university, may mean that much effort is required to gain sufficient authority to convince colleagues of the significance of the outcome of this research, in order to facilitate physics lecturers improving teaching and learning in the university physics course.

Action research has been recommended by many education researchers for teacher development in secondary schools (eg, Bell and Gilbert, 1996, p.120). In the context of university physics education, it is suggested that conducting action research may greatly help to eliminate the potential barriers between physics lecturers and physics education research. Action research may allow physicists to appreciate the difference in the paradigms of the two disciplines, as well as the significance of educational research. Accordingly, the achievement in education research can be beneficial to the university physics education in Taiwan.

10.5.4 Suggestions for further research

As mentioned at the beginning of this thesis (see section 1.1), this research aimed at improving the teaching and learning of the university physics course in Taiwan. Both the research process and the findings provided the researcher with a better insight into this area of research. This research indicates areas for future research, and these are discussed below, including research methodology and further research questions.

- ***Implications for research methodology***

Based on the experience of this research, the researcher realised that investigation and analysis of peoples' thinking and feeling is much more complex than her original expectations, based on her previous commitment to the so-called scientific methods.

Firstly, the meanings of words can vary according to the context of the research, such as the subjects' background, the status relationship between the researcher and the participants, and the culture of the research location. For example, this research found that the students tended to respond to the options of strong statements such as "completely agree/disagree". The word completely to many Taiwanese may have a more definite meaning than to people in some other countries.

Secondly, people's opinions are more likely to be multi-faceted rather than dichotomous. For example, students may feel that the lecturer is appealing, but feel that the course is boring, and vice versa. Hence, it is very risky to group peoples' opinions and lead to a final conclusion simply based on a short comment or response. Further elaboration of their comments, such as the reasons for the comments, can provide a better insight into how and what people feel.

Thirdly, some results appeared to be paradoxical from the view of common sense. For example: more students feeling interested in a course does not necessarily lead to fewer students feeling bored; better achievement in understanding physics concepts, links to the perception of a lighter workload; creating challenge in

teaching may not necessarily undermine learning confidence. These examples show that an in-depth investigation is essential to achieve a better understanding of people's thinking and prevent misinterpretation of the original data.

Finally, analysis was sometimes beyond the scope of logical derivation. Adoption of mathematical rules may distort the message that the original data indicates. For example, half the students studying for 10 hours, and half not studying at all is not equivalent to all the students studying for 5 hours, but rather, indicates that the failure rate could be as high as 50%. Therefore, researchers should be very cautious when analysing quantitative data, and should ensure the reasons for adopting the analysis procedures, and thus avoid distorting the meaning of the original data.

During the analysis procedure in this research, the researcher gradually realised the power of a more open form of investigation using techniques such as open-ended question surveys or less-structured interviews. Comparing the findings of both the closed and open-form data of this research, strengths of the open-ended investigations included: (1) identifying the students' comments more significantly with respect to different teaching, (2) distinguishing the subtle differences between similar responses, and (3) highlighting the critical issues out of all the issues raised by the researcher.

Convinced of the power of the open-form investigation, but also considering the need of quantitative data to persuade physics lecturers, the researcher suggests that a combination of open-ended questionnaire survey and interview may be optimal for further research methodology.

- ***Questions for further research***

As discussed in section 10.5.1, the limitations of this thesis may result in an overly optimistic impression of the outcomes of the intervention teaching design. Further research can address the three main limitations of this thesis and investigate the influence of these limitations on the research findings. These three limitations can be addressed in the following ways: (1) Instead of a short-term

program, further research could be conducted over a longer period such as one semester or one academic year. (2) Research combining the intervention teaching and a modification to the existing assessment is suggested. (3) It is suggested that a new teaching design be taught in a regular class by the researcher, with the status of lecturer, and there will be no acknowledgement to the students of its research purpose. It will be implemented as a regular university physics class.

Further research, addressing these three limitations, may well be to continue investigation into the students' responses towards the new teaching approach, which aims to promote the students' participation in classroom. This further research will be exploring the comparison of the new teaching with the traditional teaching. Three areas could be studied.

- (1) learning approach and achievement: How do the students perceive of learning: learning process (how to learn), learning goals (why to learn), and learning objectives (what to learn)? How do these perceptions link to their attitudes towards the teaching design and their academic achievement?
- (2) learning motivations and classroom management: How do the students' evaluate the new teaching design? Can the new teaching promote learning motivations? Do learning motivations conflict with classroom management?
- (3) academic achievement: Does the new teaching design promote the students' academic performance, particularly in their understanding of physics concepts?

The last issue may be the top priority in order to draw physics lecturers' interest in conducting an action research cooperatively with the researcher. Hopefully, the results can promote a discussion of "what and how much our students actually gained from traditional teaching" amongst physics lecturers. Lecturers' dissatisfaction with the current teaching may be the first step in the direction of teaching innovations.

Appendix A1: Survey 1F

Questionnaire survey 1F (A translation from Mandarin)

Please answer the following questions with the corresponding number.

Completely agree	Agree	Neutral	Disagree	Completely disagree
5	4	3	2	1

A: Learning attitudes and approach

What are your self-expectations about the study transition from school to university?

1. I hope to adjust my learning approach from rote learning to deeper _____ learning.
2. I expect to actively join the discussion in class instead of being a passive listener. _____
3. I hope to become an autonomous learner and be equipped with regular study habits. _____
4. I do not intend to put too much effort into my university study over the minimum requirement to pass. _____
5. I expect to be aware enough to critique the teaching material, and not always follow what the lecturers have taught. _____
6. I would like to enhance my contemporary knowledge by reading sufficient research articles. _____
7. I am willing to try to become an independent learner. _____
8. What I perceive of “study” is only limited to reading textbooks. _____

B: Goals of Learning the University Physics

Compared with high school physics, what do you expect to improve or achieve by learning University Physics?

1. I hope my physics lecturer can provide many new topics in class. _____
2. With respect to the topics taught at high school, I hope to have a deeper understanding of the physics concepts. _____
3. Through learning University Physics, I hope to promote my capability in mathematics (including calculus). _____
4. I anticipate the course can provide a knowledge basis for my majoring advanced study. _____
5. I hope to enhance my abstract thinking ability from learning this course. _____
6. From this course, I hope to become familiar with the link between physics theory and application in everyday life. _____
7. I expect to know more information about contemporary development of technology by learning physics. _____
8. I hope this course can promote my interest in investigating physics. _____
9. I hope to enhance my ability of English reading by reading the English version of the physics textbook. _____
10. Other goals you feel important for this course _____

According to your point of view, what would be the priority order of the goals of the University Physics course from the above statements? (Please fill in the number of the corresponding item starting from the most important one)

C: Your perceptions about the high school physics course:

1. I felt interested in learning high school physics _____
2. The teaching content of high school physics was relevant to everyday life _____
3. The teaching pace was too fast _____
4. The workload of high school physics was too heavy _____
5. The teaching content emphasized clarifying our understanding of physics concepts _____
6. The teaching content contained too much mathematical derivation _____

D: Reasons for difficulties in learning Physics at high school

1. I did not put enough effort into studying high school physics. _____
2. I could not find an appropriate strategy for learning physics. _____
3. In my high school class, the teaching style was monotonous. _____
4. The selected teaching content made me feel that it was too dull to learn. _____
5. I was incapable of doing the mathematical arithmetic. _____
6. I regarded physics as the most difficult subject among all of the courses in high school. _____
7. The teaching pace of high school physics was too fast. _____
8. My high school physics teacher was not able to express ideas clearly. _____
9. There were no resources to consult when I had problems studying physics out of class. _____

Questionnaire survey 1F (Chinese version)

請選擇 1 至 5 的數字表達你對各問題同意的程度。

非常同意	同意	沒意見	不同意	非常不同意
5	4	3	2	1

A：從中學進入大學，你對自己未來求學態度與方法的自我期許為：

1. 多了解觀念，少記憶背誦 _____
2. 主動參予討論，不僅被動聽講 _____
3. 養成規律且自動的讀書習慣 _____
4. 只求蒙混過關，不願再辛苦讀書 _____
5. 自主判斷課程優劣，選擇性的研讀，而非照單全收 _____
6. 多利用圖書館閱讀課外(科技)期刊 _____
7. 我願意嘗試並培養獨立學習的能力 _____
8. 所謂讀書就是讀教科書 _____
9. 其它 _____

B：與高中物理相比較，你希望在時數有限的大一普物課程中多加強下列哪些項目？

1. 增加很多新主題 _____
2. 主題相同時，物理觀念更清楚 _____
3. 數學演算(包括微積分)能力的增強 _____
4. 針對未來專業科目提供知識基礎 _____
5. 抽象思考能力的增強 _____
6. 加強物理與日常生活應用之關係 _____
7. 熟悉當今科技發展的新知 _____
8. 提昇學習物理的興趣 _____
9. 英文閱讀的提昇 _____
10. 其他應具備之重要功能 _____

依你的觀點，針對普物課程，上述各項功能其重要性之順序排列應為(填寫項目號碼) □→□→□→□→□→□

C: 你對高中物理課程的觀感是

1. 我對高中物理感到興趣 _____
2. 上課內容與生活經驗相關(實用) _____
3. 課程進度太快 _____
4. 課程負擔太重 _____
5. 教學內容重視完整物理概念的理解 _____
6. 教學內容太多數學公式推導 _____

D: 你認為妨礙你高中物理學習成效的原因為下列哪些？

1. 我不夠用功 _____
2. 我沒能調整出適合的讀書方法 _____
3. 老師的教學方式太呆板 _____
4. 上課的內容太枯燥 _____
5. 我的數學推導演算能力不足 _____
6. 物理是最難的科目 _____
7. 上課進度太快 _____
8. 老師表達能力太差 _____
9. 缺乏課後協助的資源 _____
10. 其它: _____

Appendix A2: Survey 1S

Questionnaire survey 1S (A translation from Mandarin)

Please answer the following questions with the corresponding number.

Completely agree	Agree	Neutral	Disagree	Completely disagree
5	4	3	2	1

Part A: Goals of the University Physics course

Compared to high school physics, the achievements of learning University Physics are as follow:

1. My physics lecturer provided many new topics in the physics class. _____
2. With respect to the same topics as taught at high school, I have a deeper understanding of physics concept from learning University Physics. _____
3. Through learning University Physics, my capability in mathematics (including calculus) have been enhanced. _____
4. The University Physics course provided a sufficient knowledge basis for my major courses. _____
5. I have become more capable in abstract thinking by studying this course. _____
6. Through learning University Physics, I have become familiar with the link between physics theory and applications in everyday life. _____
7. I have learnt a great deal of information about contemporary development of technology from this course. _____
8. I have become more interested in physics during the year of learning University Physics. _____
9. By reading the English version of the physics textbook, my English reading ability has improved. _____
10. Other goals you feel important for the University Physics course. _____

According to your expectation, what should be the priority order of the goals of the university Physics course from the above statements? (Please fill in the number of the corresponding item from the most important one.)

Part B: Curriculum design

What do you perceive about the curriculum design of University Physics?

1. I feel interested in learning University Physics. _____
2. The teaching content was practical and relevant to everyday life. _____
3. The teaching pace of University Physics was too fast. _____
4. The workload of studying this course was too heavy. _____
5. The teaching content emphasized comprehension of physics concepts. _____
6. There was too much algorithmic manipulation in the University Physics course. _____

Part C: Lecturer and his/her teaching

What is your perception about your physics lecturer and his/her teaching?

1. My physics lecturer is equipped with sufficient academic background in physics. _____
2. The lecturer gives lucid lectures in teaching physics. _____
3. My physics lecturer put his/her effort into encouraging students to ask and discuss questions. _____
4. He/she provided a variety of teaching approaches in teaching University Physics. _____
5. My physics lecturer supplied ample examples of applications in everyday life. _____
6. My physics lecturer established a good atmosphere in class. _____
7. Other strengths you regard as important for being a good physics lecturer. _____

According to your expectations, the priority order for being a good physics lecturer, from the above items should be _____

Part D: Obstacles in learning the University Physics

What do you conceive to be the main obstacles in learning University Physics?

1. I did not put enough effort into studying the University Physics course. _____
2. I did not have an appropriate strategy for learning physics. _____
3. There were no resources to consult when I had problems in studying physics out of class. _____
4. In my University Physics class, the teaching style was monotonous. _____
5. The selected teaching content made me feel that physics was too dull to learn. _____
6. I was incapable of the mathematical arithmetic required. _____
7. I had difficulty in reading the English version of the physics textbook. _____

Questionnaire survey 1S (Chinese version)

請選擇 1 至 5 的數字表達你對 A 到 D 四項主題中各問題同意的程度。

非常同意	同意	沒意見	不同意	非常不同意
5	4	3	2	1

主題 A：課程功能與目標

與高中物理相比較，你感覺修大一普物所得到的收穫為

1. 增加很多新主題 _____
2. 主題相同時，物理觀念更清楚 _____
3. 數學演算(包括微積分)能力的增強 _____
4. 提供未來專業科目的知識基礎 _____
5. 抽象思考能力的增強 _____
6. 學得物理在日常生活的應用 _____
7. 熟悉當今科技發展的新知 _____
8. 提昇學習物理的興趣 _____
9. 英文閱讀的提昇 _____
10. 其他應具備之重要功能 _____

依你的觀點，針對普物課程，上述各項功能其重要性之順序排列應為(填寫項目號碼) □→□→□→□→□→□

主題 B: 你對普物課程設計的觀感

1. 我對去年的普物課程感到興趣 _____
2. 上課內容與生活經驗相關(實用) _____
3. 課程進度太快 _____
4. 課程負擔太重 _____
5. 教學內容重視完整物理概念的理解 _____
6. 教學內容太多數學公式推導 _____

主題 C：有關你的物理老師及其教學

1. 老師具備了足夠的物理專業知識 _____
2. 老師具備了良好的語言表達能力 _____
3. 課堂上老師常鼓勵同學發問並參予討論物理觀念(不僅是單向傳授) _____
4. 老師會嘗試各種教學方式或教具 _____
5. 針對物理理論補充生活上之實用例證 _____
6. 提供良好上課氣氛 _____
7. 其它你認為物理老師所需具備要項_____

依你的觀點，針對老師教學，上述各項其重要性之順序排列應為(填寫項目號碼) □→□→□→□→□

主題 D：你認為自己普物學的不好的是的原因是

1. 我不夠用功 _____
2. 我沒能調整出適合的讀書方法 _____
3. 遇到問題時沒有資源(包括老師、同學)幫助我解決 _____
4. 老師的教學方式太呆板 _____
5. 上課的內容太枯燥 _____
6. 我的數學推導演算能力不足 _____
7. 我的英文閱讀能力太差 _____

Appendix A3: Survey 2

Questionnaire survey 2 (A translation from the Mandarin)

Part I Teaching content	Agree	Disagree	No comment
1. I feel that the teaching content of the university physics course <u>repeats</u> too much of the high school physics.	_____	_____	_____
2. I feel that the teaching pace of this course is <u>too fast</u> .	_____	_____	_____
3. I wish that the university physics course could supply more examples of applications in <u>everyday life</u> .	_____	_____	_____
4. I wish that the university physics course could reduce some classical topics in order to introduce more <u>modern</u> topics.	_____	_____	_____
5. I have lost my confidence in learning physics because the teaching materials are <u>too difficult</u> .	_____	_____	_____
6. I feel sleepy in physics class, because the course is <u>too boring</u> .	_____	_____	_____
7. I expect that the content of this course can be adjusted to support my <u>majoring courses</u> .	_____	_____	_____
8. I agree that it is <u>worthwhile</u> to take this course.	_____	_____	_____
9. Taking the university physics course <u>promotes my interest</u> in investigating physics.	_____	_____	_____
10. From this course, I have learnt only <u>discrete</u> knowledge instead of integrated concepts.	_____	_____	_____
11. The content of the <u>examinations matches</u> the teaching content in physics class.	_____	_____	_____

Part II Teaching approach

	Agree	Disagree	No comment
1. The teaching approach of the university physics course is <u>appealing</u> .	_____	_____	_____
2. I hope that my physics lecturer can introduce an <u>interactive</u> teaching approach in class.	_____	_____	_____
3. I feel that the <u>traditional lecturing</u> method is suitable to the university physics course.	_____	_____	_____
4. I expect my physics lecturer to adopt <u>live-demonstrations</u> throughout this course.	_____	_____	_____

Part III Learner self-assessment

1. I regard myself as being equipped with <u>regular study</u> habits.	_____	_____	_____
2. I <u>discuss</u> with my classmates when facing some unsolved problems.	_____	_____	_____
3. I <u>reflect</u> on my learning outcomes and try to adjust my learning approach.	_____	_____	_____
4. After studying at the university, I have become more <u>active</u> in my learning process.	_____	_____	_____
5. After studying at the university, I have become <u>deeper</u> and more <u>flexible</u> in my learning approach.	_____	_____	_____
6. In the physics class, I <u>pay attention</u> to my teacher's lecturing.	_____	_____	_____
7. While preparing for the examination, I will still <u>memorise the physics formulas</u> even if I don't understand the concepts behind them.	_____	_____	_____
8. I will put in the <u>minimum effort to pass</u> this course since I have no interest at all in learning physics.	_____	_____	_____

Part IV Conclusions and suggestions

1. If the university physics curriculum is going to be innovative, which weakness do you think should be improved? which strength should be continued?
2. Please make comments on the university physics course overall.

I: 課程	同意	不同意	沒意見
1. 我感覺普物所教內容與高中所學 <u>重覆太多</u>	_____	_____	_____
2. 我感覺普物課程 <u>進度太快</u>	_____	_____	_____
3. 我希望普物教材能多補充 <u>生活上應用的實例</u>	_____	_____	_____
4. 我希望教材能減少古典物理, 增加 <u>近代物理</u> 單元	_____	_____	_____
5. 普物教材內容太難, 打擊我的信心	_____	_____	_____
6. 普物課程太枯燥, 使我昏昏欲睡	_____	_____	_____
7. 我希望普物教材能 <u>針對各系</u> 有不同的設計	_____	_____	_____
8. 我感覺修普物是 <u>值得的</u>	_____	_____	_____
9. 普物課程增進了我對物理的 <u>興趣</u>	_____	_____	_____
10. 我只學到 <u>零星的知識</u> , 沒有完整的物理概念	_____	_____	_____
11. 普物考試題目與上課內容 <u>配合</u>	_____	_____	_____
II: 教法			
1. 普物課上課方式, 對我具 <u>吸引力</u>	_____	_____	_____
2. 我希望普物課能引入 <u>互動式</u> 教法	_____	_____	_____
3. 普物課適合採傳統的 <u>演講式</u> 教法	_____	_____	_____
4. 我希望普物課老師能多引用 <u>示範實驗</u> 教學	_____	_____	_____
III: 學習者			
1. 我具備了 <u>規律的</u> 讀書習慣	_____	_____	_____
2. 遇到問題, 我會找同學 <u>討論</u>	_____	_____	_____
3. 我會反省並嘗試調整自己的讀書方法	_____	_____	_____
4. 進大學後, 我的讀書態度更 <u>主動</u>	_____	_____	_____
5. 進大學後, 我的讀書方法更 <u>靈活</u>	_____	_____	_____
6. 普物課堂上, 我有 <u>用心</u> 聽講	_____	_____	_____
7. 在考前, 我仍會將 <u>不懂的</u> 公式背起來以應付考試	_____	_____	_____
8. 我對物理沒興趣, <u>只求及格</u> 過關	_____	_____	_____
IV: 總評與建議			
1. 如果普物課程將進行調整, 您覺得那些缺失應改進? _____			
那些特點應保存? _____			
2. 請給整體普物課程下一個總評 _____			

Appendix A4: Survey 3A

Questionnaire survey 3A (A translation from Mandarin)

I. Basic information

Age ____	Sex ____	Entrance exam score in physics ____
High school category: private /public		Year of graduation from high school : ____
High school physics class time: (hour/week)		
1 st yr ____ + 2 nd yr ____ + 3 rd yr ____ = _____		
If there were any extra physics classes, please note here: _____		

Please respond to the statement in II, III, IV below using the corresponding numbers.

agree	slightly agree	neutral	slightly disagree	disagree
5	4	3	2	1

II. What you expect to achieve from learning university physics.

I expect to ...

- | | |
|---|-----------|
| ___ 1. have a deeper comprehension of <u>physics theories</u> | 5 4 3 2 1 |
| ___ 2. learn many <u>applications in life</u> from physics theory | 5 4 3 2 1 |
| ___ 3. enhance my <u>mathematics skills</u> | 5 4 3 2 1 |
| ___ 4. learn only what will appear in the <u>examination</u> | 5 4 3 2 1 |
| ___ 5. cultivate my <u>logical reasoning</u> ability | 5 4 3 2 1 |
| ___ 6. be equipped with the knowledge <u>base for</u> the advanced courses of my <u>major</u> | 5 4 3 2 1 |
| ___ 7. develop a more efficient <u>learning approach</u> | 5 4 3 2 1 |
| ___ 8. <u>pass the course</u> with very little effort | 5 4 3 2 1 |

Please go back to the statements in part II and choose two items that you think are the most important. Write 1 for the top priority and 2 for the second priority on the dash.

agree	slightly agree	neutral	slightly disagree	disagree
5	4	3	2	1

III. To what extent do you plan to do the following activities when learning university physics? I expect that

- | | | | | | |
|---|---|---|---|---|---|
| 1. Even if my lecturer does not take the attendance, I will attend every physics class | 5 | 4 | 3 | 2 | 1 |
| 2. The major task for me in a physics class will be to copy everything the lecturer writes | 5 | 4 | 3 | 2 | 1 |
| 3. Discussing with peers or the lecturer will help me to understand the concept | 5 | 4 | 3 | 2 | 1 |
| 4. I will prefer to study physics alone | 5 | 4 | 3 | 2 | 1 |
| 5. I will be only willing to discuss questions with peers who have a better level of achievement than me. | 5 | 4 | 3 | 2 | 1 |
| 6. I will synthesize the concepts in the different topics | 5 | 4 | 3 | 2 | 1 |
| 7. My main task in studying physics will be to practice problem-solving. | 5 | 4 | 3 | 2 | 1 |
| 8. To study physics, I will read the textbook. | 5 | 4 | 3 | 2 | 1 |
| 9. To study physics, I will not do anything except memorise formulas before the examination | 5 | 4 | 3 | 2 | 1 |
| 10. It will take _____ hrs/wk, out of class, to learn all I need to learn from this course. | | | | | |

IV. What do you expect the lectures to do for you ?

I expect my physics lecturer to

- | | | | | | |
|---|---|---|---|---|---|
| ___ 1. lecture on all the content in the textbook | 5 | 4 | 3 | 2 | 1 |
| ___ 2. clarify the important concepts from the textbook | 5 | 4 | 3 | 2 | 1 |
| ___ 3. show us the skill of problem-solving | 5 | 4 | 3 | 2 | 1 |
| ___ 4. link physics theory and applications in everyday life | 5 | 4 | 3 | 2 | 1 |
| ___ 5. be aware of student learning while teaching | 5 | 4 | 3 | 2 | 1 |
| ___ 6. perform demonstrations while teaching | 5 | 4 | 3 | 2 | 1 |
| ___ 7. adopt an interactive teaching approach | 5 | 4 | 3 | 2 | 1 |
| ___ 8. stimulate the engagement of students in class discussion | 5 | 4 | 3 | 2 | 1 |
| ___ 9. give hand-outs | 5 | 4 | 3 | 2 | 1 |
| ___ 10. present humorous lectures | 5 | 4 | 3 | 2 | 1 |
| ___ 11. provide reference information beyond the textbook | 5 | 4 | 3 | 2 | 1 |

Please go back to the statements in part IV and choose three items that you think are the most important. Write 1 for the top priority and 2 and 3 for the following priorities on the dash.

各位同學們:

你們好！我是逢甲物理中心的老師，正在執行普通物理課程的檢討與改革研究。這份問卷主要是想瞭解你對普通物理的課程目標、教學、及學習態度的意見。

回答這份問卷大約需花費 10 -15 分鐘，希望你能熱心參與，謝謝！

年齡 _____	性別 ____	民國_____年，高中畢業
聯考物理成績 _____		高中類別: 公、私立 _____
高中物理上課時數: (小時/週)		
高一 __, 高二 __, 高三 __, 其它額外時數 _____		

回答以下 I, II, III 三部份，請根據你同意的程度圈出相對應 1-5 的數字。

同意	些微同意	沒意見	些微不同意	不同意
5	4	3	2	1

I. 未來的一年，你期望能夠從普物課程中，學到下列那些？

我期望能夠.....

- | | |
|-------------------------|-----------|
| ___ 1. 對物理的理論有更紮實的瞭解 | 5 4 3 2 1 |
| ___ 2. 熟悉物理在生活及現代科技上之應用 | 5 4 3 2 1 |
| ___ 3. 增強數學演算(包括微積分)的能力 | 5 4 3 2 1 |
| ___ 4. 只讀可能出現在考試題目內的內容 | 5 4 3 2 1 |
| ___ 5. 強化我思考推理的能力 | 5 4 3 2 1 |
| ___ 6. 學得未來專業科目所需要的知識基礎 | 5 4 3 2 1 |
| ___ 7. 領會出更好的讀書方法 | 5 4 3 2 1 |
| ___ 8. 只求及格過關 | 5 4 3 2 1 |

請再回到前面八個選項中，挑選出你認為最重要一至二項，並在項目前的橫線上，分別標出 1, 2。(1 代表最重要之項目)

(請翻背面繼續回答)

同意	些微同意	沒意見	些微不同意	不同意
5	4	3	2	1

II. 未來一年，你打算如何學普物？

1. 即使老師不點名，我還是會去上普物課 5 4 3 2 1
 2. 在普物課堂上，我主要的任務是將黑板上的內容全部抄下來 5 4 3 2 1
 3. 與同學或老師討論對學物理很有幫助 5 4 3 2 1
 4. 我偏好自己獨自研讀物理 5 4 3 2 1
 5. 我只願意與程度比我好的同學討論物理問題 5 4 3 2 1
 6. 我會綜合數個章節的內容，並作成總結 5 4 3 2 1
 7. 學物理，我的主要工作是練習解習題 5 4 3 2 1
 8. 學物理，我會閱讀教科書的內容 5 4 3 2 1
 9. 我只打算考前背背公式，應付考試即可 5 4 3 2 1
- * 在課後，我打算花 _____ 小時/週，研讀普物。

III. 你期望你的普物老師在教學上應該為你作那些？

我期望我的普物老師能夠.....

- ___ 1. 完整的講解教科書的內容 5 4 3 2 1
- ___ 2. 整理出教材主要的重點 5 4 3 2 1
- ___ 3. 多教我們解題的技巧 5 4 3 2 1
- ___ 4. 多介紹理論在生活上之應用 5 4 3 2 1
- ___ 5. 教學時能注意學生的學習效果 5 4 3 2 1
- ___ 6. 引用示範實驗教學 5 4 3 2 1
- ___ 7. 採用互動式的教學 5 4 3 2 1
- ___ 8. 誘導同學參與討論的意願 5 4 3 2 1
- ___ 9. 發講義給同學 5 4 3 2 1
- ___ 10. 上課風趣幽默 5 4 3 2 1
- ___ 11. 廣泛搜集課外的補充資料 5 4 3 2 1
- ___ 12. 其它 _____

請再回到前面八個選項中，挑選出你認為最重要一至三項，並在項目前的橫線上，分別標出 1, 2, 3。(1 代表最重要之項目)

Appendix A5: Survey 3B

Questionnaire survey 3B (A translation from Mandarin)

Please respond to the statements below using the corresponding numbers.

agree	slightly agree	neutral	slightly disagree	disagree
5	4	3	2	1

- From the past learning experiences in university physics, how do you **feel** about the course?

THE TEACHING

1. My physics lecturer has adopted a one-directional delivery teaching method. 5 4 3 2 1
2. I regard an interactive teaching method as more effective in helping learning than one way delivery. 5 4 3 2 1
3. My physics lecturer has clarified clearly the key points of his/her teaching materials. 5 4 3 2 1
4. My physics lecturer has provided plenty of reference information linked to everyday life in his/her teaching content. 5 4 3 2 1
5. In the physics class, the teaching methods are monotonous. 5 4 3 2 1
6. The teaching content in my physics class can induce my interest in learning. 5 4 3 2 1
7. My physics lecturer should reduce the teaching time spent on mathematical derivation. 5 4 3 2 1
8. My physics lecturer has been aware of our learning outcomes while teaching. 5 4 3 2 1
9. I have very good learning achievements from the physics lessons. 5 4 3 2 1
- *10. The teaching time spent on discussion should be used on other activities, which are more important. 5 4 3 2 1
- *11. In-class discussion helps me a lot in understanding the physics concepts. 5 4 3 2 1
- *12. My physics background is too weak to cope with discussion. 5 4 3 2 1

* Questions 10, 11, 12 were given to the intervention class only

agree	slightly agree	Neutral	slightly disagree	disagree
5	4	3	2	1

THE LEARNING

1. In the physics class, I feel that learning physics is a matter of enjoyment. 5 4 3 2 1
2. If my lecturer won't record the attendance, I will not attend the physics class. 5 4 3 2 1
3. I concentrate on listening to the lecture in the physics class. 5 4 3 2 1
4. In the physics lessons, I am engaged in active thinking. 5 4 3 2 1
5. In the physics class, I am involved in the discussions. 5 4 3 2 1
6. I understand how to adopt a more flexible and deeper learning strategy from the university physics lessons. 5 4 3 2 1
7. I am not interested in physics at all; I just expect to pass the course with minimum effort. 5 4 3 2 1
8. Please evaluate how many study hours per week have you spent out-of-class on studying physics. _____ hr/wk .

agree	slightly agree	neutral	slightly disagree	disagree
5	4	3	2	1

THE COURSE

1. The physics lessons promote my interest in learning. 5 4 3 2 1
2. The physics lessons enhance my physics concepts. 5 4 3 2 1
3. I have only learnt discrete pieces of knowledge, not integrated concepts. 5 4 3 2 1
4. Regarding the physics course overall, I feel satisfied with it. 5 4 3 2 1
5. The physics lessons reinforce my confidence. 5 4 3 2 1
6. The physics lessons develop my thinking ability. 5 4 3 2 1
7. Till now, I have learnt nothing from this course. 5 4 3 2 1

II. Conclusions and Suggestions

1. What do you like about this class? Why do you like it? (Please use your own words to express your opinions)

I like _____
because _____

2. What do you dislike about this class? Why do you dislike it?

I dislike _____
because _____

3. Do you wish to let your physics lecturer read the result of this questionnaire survey? Yes _____; No _____

各位同學們:

藉由這份問卷，希望能瞭解你對過去三周來普物課程與教學的看法。回答這份問卷大約需花費 10 分鐘，謝謝你的參與！

● 開學至今，普物課給你什麼感覺？

請根據你同意的程度圈出相對應的數字。

同意	些微同意	沒意見	些微不同意	不同意
5	4	3	2	1

教法與教材

- | | |
|---|-----------|
| 1. 我的普物老師採取單向灌輸的教學法 | 5 4 3 2 1 |
| 2. 我認為雙向的 <u>互動式</u> 比單向的 <u>灌輸式</u> 教法更有助於學習 | 5 4 3 2 1 |
| 3. 老師的上課內容， <u>重點</u> 很清晰 | 5 4 3 2 1 |
| 4. 普物老師補充了很多 <u>生活化</u> 的教材 | 5 4 3 2 1 |
| 5. 普物課的上課方式很 <u>單調</u> | 5 4 3 2 1 |
| 6. 普物的上課內容，能引發我學習的 <u>興趣</u> | 5 4 3 2 1 |
| 7. 老師應該 <u>減少</u> 上課時用於 <u>數學</u> 推導的時間 | 5 4 3 2 1 |
| 8. 老師在教學的過程中，會注意同學的 <u>學習效果</u> | 5 4 3 2 1 |
| 9. 上物理課，我感覺很有 <u>收穫</u> | 5 4 3 2 1 |
| 10. 課堂上討論所佔用的時間，應該可以拿來用在更重要的事情上 | 5 4 3 2 1 |
| 11. 課堂上的討論，對我觀念的理解很有 <u>幫助</u> | 5 4 3 2 1 |
| 12. 我的物理背景太差，所以 <u>無法</u> 參與討論 | 5 4 3 2 1 |

同意	些微同意	沒意見	些微不同意	不同意
5	4	3	2	1

學習

1. 在普物課中，我感覺學物理是一件愉快的事 5 4 3 2 1
2. 假如老師不點名，我就不會去上普物課 5 4 3 2 1
3. 普物課，我有專心聽講 5 4 3 2 1
4. 普物課，我有用心思考 5 4 3 2 1
5. 普物課堂上，我有參與討論 5 4 3 2 1
6. 經由普物課，我領悟了更靈活的讀書方法 5 4 3 2 1
7. 我對物理毫無興趣，只求及格過關 5 4 3 2 1
8. 請評估自己，在課後平均每每周花多少時數研讀普通物理 _____ 小時/周

課程總評

1. 上普物提高我對物理的興趣 5 4 3 2 1
2. 上普物課增強了我的物理觀念 5 4 3 2 1
3. 普物課，我只學到瑣碎的知識，沒有完整的概念 5 4 3 2 1
4. 整體來講，我對普物課程感到滿意 5 4 3 2 1
5. 普物課增強我的自信心 5 4 3 2 1
6. 普物課鍛鍊我的思考力 5 4 3 2 1
7. 到目前為止，我沒有從普物這門課中學到任何東西 5 4 3 2 1

II. 總結與建議

1. 普物課 (不含實驗)，是否有那些你所喜歡的特點? 為什麼?(請用自己的話敘述)

我喜歡 _____ ,

因為 _____

2. 普物課 (不含實驗)，是否有那些令你不喜歡的缺點? 為什麼?

我不喜歡 _____ ,

因為 _____

Appendix A6: Student interview

STUDENT INTERVIEW QUESTIONS

Name: _____	Class __	Age _____	Entrance exam score in physics ____
Date _____	Code # _____	Comments _____	

I. Learning

1. What have you done in physics class?
 - (a.) note-taking: verbatim or summarizing
 - (b.) pay attention or day dream? Why can't you focus?
 - (c.) actively discussing or not? Why not discussing?

2. What have you done to learn physics out-of-class?
 - (a) regular study habit? _____, study hour? _____ hr/wk
 - (b) reading text/notes (concept) or practicing problem-solving?
 - (c) reading reference articles or not?

3. What is most beneficial to your learning?
 listening to the lecture, taking notes, discussion, problem-solving, sitting tests

4. What will you do if you have problems in learning physics?
 keep thinking alone, read the textbook/ notes, read the solution, ask others,
 discuss with others

5. How do you feel about your learning outcomes?
 - a. Are you satisfied with your learning outcome in university physics?
 Which weakness makes you dissatisfied?
 - b. Do you wish to make any modification to your learning approach?
 - c. Why do you think some students can learn better than you?

II. Teaching content

1. How do you feel about the teaching content of the university physics course?

Strengths & Weaknesses?

Which aspects of the teaching content should be selected in university physics course?

2. What was the taught unit that you liked the most? Why did you like it?

3. What was the taught unit you disliked the most? Why did you dislike it?

III. Teaching approach

1. How well did your lecturer teach?

A. reasonable pace?

B. clarity/ structure ?

C. establish confidence?

D. promote interest?

E. efficient in helping learning?

F. induce engagement?

2. What were the strengths and weaknesses of the teaching approach?

Suggestions for improvement?

3. The major task for my physics lecturer in class should be _____

4. What are the characteristics of a good physics lecturer?

IV. Comments on and suggestions for the university physics course overall.

學生訪談

姓名 _____	年齡 _____	班級 _____	性別 _____	編號: _____
聯考物理成績 _____	日期 _____	時間 _____	總評 _____	

I. 學習

1. 你在普物課堂上主要的學習活動是什麼?
 - A. 抄筆記: 抄下所有板書, 歸納重點或困難
 - B. 用心思考 vs. 胡思亂想? _____ (為何不能用心? _____)
 - D. 主動發問 / 參予討論? _____ (為何不發問, 討論? _____)
2. 你在普物課之課外時間如何複習/預習?
 - A. 是否規律? _____, 讀書時數 _____
 - B. 著重課本, 筆記(觀念) 或 練習解題? _____,
 - C. 閱讀課外讀物 _____
3. 你認為對你學習普物效果最有幫助的是什麼? (活動或教材) _____
 - A. 上課聽講, B. 複習筆記/課本, C. 練習解題, D. 看題解 E. 討論, F. 其它
4. 當你讀物理碰到困難時, 你如何解決? _____
 - A. 再深入思考/閱讀, B. 找題解, C. 立刻問人, D. 與同學討論
5. 你覺得學習普物的成效有那些? _____
 - A. 感到滿意? 為什麼? _____
 - B. 主要的學習障礙, 應該如何改進?
 - C. 有些同學為什麼可以學得比較好?

II. 教學內容

1. 你對普物課的教學內容，感覺如何? _____

優缺點? _____

物理課應著重那些內容? _____

2. 在普物課教過的單元中,你最喜歡那一項? 爲什麼?

3. 在普物課教過的單元中,你最不喜歡那一項? 爲什麼?

III. 教法

1. 你感覺你的物理老師教學方法與技巧如何?

A. 進度適中

B. 重點清晰有條理

C. 建立學習者信心

D. 生動活潑

E. 教學效果好

F. 課堂內之互動

2. 老師教學上之優缺點? _____

改進意見? _____

3. 你認爲老師在課堂上，主要的任務是什麼?(教學活動)

4. 好物理老師老師的特點? _____

IV. 總評與建議

Appendix A7: Consent form

Consent Form for the Second Year Students (survey 1S)

(A translation from Mandarin)

Dear Students,

After one year of learning the university physics, you must have some comments about this course, either positive or negative. This questionnaire is a study of how to improve the teaching outcomes of the University Physics course, for my thesis. I am a physics lecturer at Feng-chia University and presently have been studying for a doctoral degree at the University of Waikato in New Zealand. Filling in this questionnaire will take you about 20 to 30 minutes. Your co-operation in this matter would be very greatly appreciated. The completed questionnaires will be kept confidential and only the researcher will evaluate the contents.

Please tick the box if you are willing to fill in this questionnaire.

Wheijen Chang

(Consent form for survey 1S)

各位同學們:

你們好！我是逢甲物理中心的老師，正在執行一項普物課程的檢討與改革的研究。去年一年的物理課，你覺得滿意嗎？失望嗎？相信你有很多寶貴的觀感、收穫、批評及建議。

這是不記名問卷，請以你個人的立場回答，不須考慮其他同學或老師的想法。回答這份問卷大約需花費 20 至 30 分鐘，希望你能熱心參與，謝謝！

願意答覆這份問卷者請打勾。

Consent Form for the First Year Students (survey 1F)

(A translation from Mandarin)

Dear students,

After passing the Entrance Exam and successfully entering Feng-Chia University, you might have some opinions about year past high school education as well as expectations for you coming tertiary education. This questionnaire is a study of how to improve the teaching outcomes of the course of University Physics, for my thesis. I am a physics lecturer at Feng-Chia University and presently have been
'Besides of the research results and comments from foreign countries, your opinions will become precious resources for this research of improving our own university physics education and to enhance the function of this course in the future.

Filling in this questionnaire will take you about 20 to 30 minutes. Your co-operation in this matter would be very greatly appreciated.

Please tick the box if you are willing to fill in this questionnaire.

Wheijen Chang

(Consent form for survey 1F)

各位同學們:

你們好！對於剛剛踏進大學的你們，想必對過去接受的高中教育有許多意見，更對即將面對的大學課程有所期許。我是逢甲物理中心的老師，正在執行一項普通物理課程的檢討與改革的研究。這是不記名問卷，請以你個人的立場回答，不須考慮其他同學或老師的想法。回答這份問卷大約需花費 20 至 30 分鐘，希望你能熱心參與，謝謝！

願意答覆這份問卷者請打勾。

Consent form for survey 2

(A translation from Mandarin)

Dear Students,

This questionnaire is for a study of how to improve the teaching outcomes of the university physics course. I am a physics lecturer at Feng-chia University and am presently studying for a doctoral degree in New Zealand. Besides the research results and comments from foreign countries, your opinions will become precious resources for this research to improve our own university physics education and to promote the function of this course in the future.

Filling in this questionnaire will take you about 15 minutes, and the completed questionnaires will be kept confidential. Although it is not compulsory to complete this questionnaire, your co-operation in this matter would be very greatly appreciated. The completed questionnaires will be kept confidential and only the researcher will evaluate the contents. Thank you for your assistance!

Please tick the box if you are willing to fill in this questionnaire.

Wheijen Chang

(Consent form for survey 2)

各位同學們:

你們好！我是逢甲物理中心的老師，正在執行一項普物課程的檢討與改革的研究。除了參考國外教育理論及研究成果之外，你的意見更將是我珍貴的研究資源。這是不記名問卷，請以你個人的立場回答，不須考慮其他同學或老師的想法。回答這份問卷大約需花費15分鐘，此問卷之填寫非強迫性質，但希望你能熱心參與，謝謝！

願意答覆這份問卷者請打勾。

Appendix B1: Outlines of lecturer interview

Outlines of lecturer interviews

Name:	Year of teaching:	Code #:	date:
Interview time:	Phone:	email:	
Teaching :			
(i) Support from the university			
(ii) Restriction			
(iii) Resources			
(iv) Teaching commitment/responsibility			
Goals of the course:			
(i) Clarification, Flexibility, Fulfillment			
(ii) Content knowledge, Learning attitude, Learning ability			
Curriculum design:			
Content			
Approach: (1) evaluation of conventional,			
(2) possible strengths of interactive teaching approach,			
(3) barriers to interactive teaching approach			
Assessment: (1) guiding learning,			
(2) validity,			
(3) alternative methods,			
(4) individual diversity			
Learning:			
(i) Academic performance			
(ii) Affective outcomes			
(iii) Learning engagement/commitment/attitudes			
(iv) Criteria & purpose of failing students			
(v) Main learning barriers: (1) student, (2) teacher, (3) curriculum design			

Appendix B2: Lecturer Survey

Lecturer survey (A translation from Mandarin)

I: What are your opinions about the results of the student survey in April 1998 (survey 2)?

1. Do you feel the results will be a useful reference for your future teaching?

2. Are there any opinions from students surprising in the light of your original perceptions? Please describe them.

3. Is there any bias that you feel may exist in the design of the student questionnaire? Please give your comments and suggestions to the researcher.

4. Do you think students expressed their real opinions of what they felt about this course?

5. In your judgment, does the student survey show that the attitude of many of the students is that they want to have an easy time when studying physics rather than wanting to improve their learning?

What are your opinions towards the teaching and learning of the course with respect to the results of the student survey?

II. Some prevalent problems exist in teaching university physics. What are your opinions about these problems, and can you suggest some possible solutions?

● ***“The teaching time is extremely tight”***

(Possible options for addressing this problem are listed below. Please list any applicable numbers or use your own words to outline a strategy.)

1. Within the limited teaching time, what do you think a lecturer should focus on when selecting teaching content?

What should be avoided? _____

- | | |
|---|---|
| 1. cover the content in the textbook | 2. summarize the key point in each lesson |
| 3. synthesize the concepts in several chapters | 4. derive and verify each theorem |
| 5. introduce examples to elucidate the physics concepts | 6. link the theory and application in everyday life |
| 7. solve the problems and teach the solving skill | 8. provide the knowledge base for advanced courses |
| 9. provide reference information beyond the textbook | 10. others |

(Possible options for teaching approaches are listed below. Please list numbers or use your own words to describe your preferences)

2. With respect to our teaching environment, which teaching approach do you think is feasible and can promote student learning outcomes?

Which teaching approach do you think can promote student learning outcomes but has barriers to implementation under the existing limitations?

- | | |
|--|---|
| 1. give hand-outs | 2. give assignments |
| 3. call on students to answer questions | 4. adopt in-class discussion |
| 5. guide students to a deeper approach | 6. introduce examples from everyday life |
| 7. monitor student learning habits | 8. introduce hi-tech & occasional stunts topics |
| 9. be concerned with student learning pace | 10. give quizzes |
| 11. adopt other teaching aids, e.g. _____ | 12. others |

- *“Many students have low motivation and engagement in physics classes....”*

1. In what ways could we promote the learning interest of our students in a physics class?

2. Will the consideration of promoting student learning interest compete with the consideration of maintaining the standard of the university physics course?

Is there any modification in the teaching design that could be beneficial to both learning interest and learning achievement?

III. Finally, please give your comments or suggestions regarding the design of this lecturer questionnaire.

您好！茲附上上學期期末(87年4月)的學生問卷結果供您參考。

爲了能進一步探討老師們的觀點，希望能再次煩請您撥冗回答這份問卷，這份問卷採簡答及選擇方式，大約需花費 20-30 分鐘回答。謝謝您的協助！

張慧貞 敬上

I: 針對上學期期末(87年4月)的學生問卷結果，

1. 您覺得這份報告對您未來的教學是否有參考價值? _____
2. 是否有那些學生的意見出乎您意料之外? 請略述之

3. 您是否感覺這份學生問卷在用語及設計上有偏頗、誘導或考慮不全之處?
請針對這份學生問卷的設計提出您的建議。

4. 您認爲學生是否真實反應他們的真正意見? _____
5. 您認爲多數學生所反應的意見，是爲了改進教學(學習)效果，或只是爲讓上課更輕鬆? _____
6. 綜合學生之意見，您對普物的教與學有何看法? (請自由發揮)

II. 有幾個普遍存在普物教學上的問題，希望能藉此機會進一步瞭解您的觀點。

● “普物課的上課的時數太少了.....”

1. 在現有的時數及其它客觀條件限制之下，您認為普物老師在上課中應加強那些內容？(請依其重要性之順序回答)

省略那些內容? _____

(可能的選項如下，請填上號碼，或用您自己的話寫出您的其它看法)

- | | |
|-----------------|-------------------|
| 1. 完整講解教科書的內容 | 2. 歸納出每堂課之重點 |
| 3. 綜合整理數章之概念 | 4. 定理的推導與證明 |
| 5. 引用實例以闡明物理觀念 | 6. 介紹物理在生活及科技上之應用 |
| 7. 講解習題例題，及解題技巧 | 8. 提供本科系之相關知識 |
| 9. 提供課外的補充資料 | 10. 其它 |

2. 在現有資源之下，您認為那些“教學活動”在普物教學上是可行，且有助於學生之學習效果？(請按重要性順序排列)

那些“活動”很值得嚐試，但實行上有其困難?請敘述其活動及困難所在。

(可能的選項如下，請填上號碼，或用您自己的話寫出您的其它意見)

- | | |
|----------------------|----------------|
| 1. 發講義給同學 | 2. 指定作業 |
| 3. 上課中抽問同學 | 4. 引用課堂討論 |
| 5. 提示同學更紮實的讀書方法 | 6. 引用生活實例 |
| 7. 強調規律之讀書習慣 | 8. 引用新奇(高科技)題材 |
| 9. 關心學生之學習進度 | 10. 時常小考、抽考 |
| 11. 採用其它教學媒體如: _____ | 12. 其它 |

● “多數學生在普物課中學習動機及參與感偏低....”

1. 有那些方法，或許可以提高學生的上課情緒及興趣?

2. 提高學習興趣的考量，是否會與課程的品質(水準)相衝突? 教學設計上是否有什麼方法可以同時兼顧興趣與品質?

III. 最後，您是否對這份教師問卷的設計有任何評語及建議?

再次謝謝您寶貴的意見!!

Appendix C1: Force Concept Inventory

1. Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant. The time it takes the balls to reach the ground below will be
 1. about half as long for the heavier ball as for the lighter one.
 2. about half as long for the lighter ball as for the heavier one.
 3. about the same for both balls.
 4. considerably less for the heavier ball, but not necessarily half as long.
 5. considerably less for the lighter ball, but not necessarily half as long.

2. The two metal balls of the previous problem roll off a horizontal table with the same speed. In this situation
 1. both balls hit the floor at approximately the same horizontal distance from the base of the table.
 2. the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
 3. the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
 4. the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.
 5. the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.

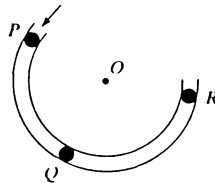
3. A stone dropped from the roof of a single-story building to the surface of Earth
 1. reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
 2. speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to Earth.
 3. speeds up because of an almost constant force of gravity acting upon it.
 4. falls because of the natural tendency of all objects to rest on the surface of Earth.
 5. falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

4. A large truck collides head-on with a small compact car. During the collision
 1. the truck exerts a greater amount of force on the car than the car exerts on the truck.

2. the car exerts a greater amount of force on the truck than the truck exerts on the car.
3. neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
4. the truck exerts a force on the car but the car does not exert a force on the truck.
5. the truck exerts the same amount of force on the car as the car exerts on the truck.

Use the statement and figure below to answer the next two questions (5 and 6).

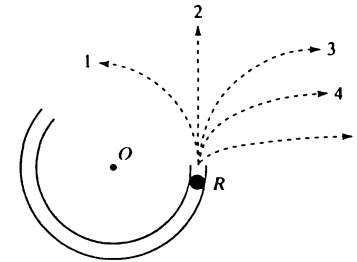
The accompanying figure shows a frictionless channel in the shape of a segment of a circle with its center at O . The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at P and exits at R .



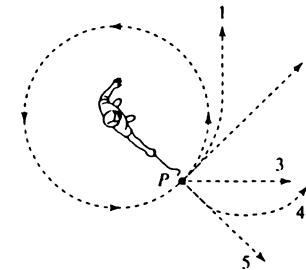
5. Consider the following distinct forces:
 - A. a downward force of gravity.
 - B. a force exerted by the channel pointing from Q to O .
 - C. a force in the direction of motion.
 - D. a force pointing from O to Q .

Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position Q ?

1. A only.
 2. A and B.
 3. A and C.
 4. A, B, and C.
 5. A, C, and D.
6. Which of the paths 1–5 below would the ball most closely follow after it exits the channel at R and moves across the frictionless table top?

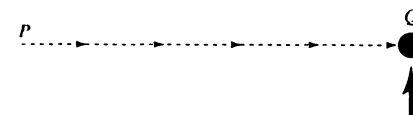


7. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the figure below. At point P , the string suddenly breaks near the ball. If these events are observed from directly above, which of the paths 1–5 below would the ball most closely follow after the string breaks?

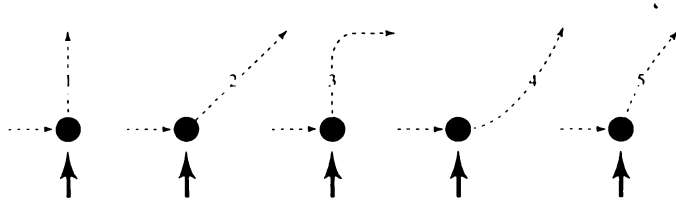


Use the statement and figure below to answer the next four questions (8–11).

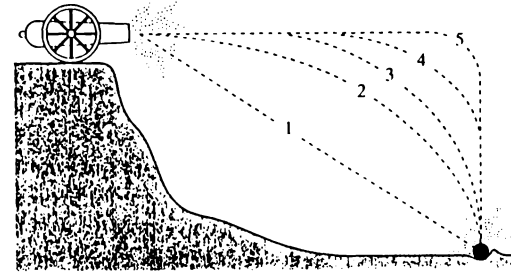
The figure depicts a hockey puck sliding with constant speed v_0 in a straight line from point P to point Q on a frictionless horizontal surface. Forces exerted by the air are negligible. You are looking down on the puck. When the puck reaches point Q , it receives a swift horizontal kick in the direction of the heavy print arrow. Had the puck been at rest at point P , then the kick would have set the puck in horizontal motion with a speed v_k in the direction of the kick.



8. Which of the paths 1–5 below would the puck most closely follow after receiving the kick?

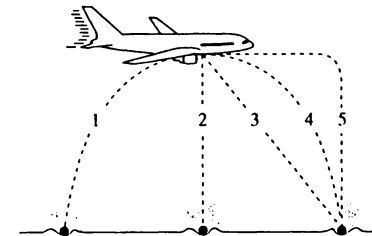


9. The speed of the puck just after it receives the kick is
 1. equal to the speed v_0 it had before it received the kick.
 2. equal to the speed v_k resulting from the kick and independent of the speed v_0 .
 3. equal to the arithmetic sum of the speeds v_0 and v_k .
 4. smaller than either of the speeds v_0 or v_k .
 5. greater than either of the speeds v_0 or v_k , but less than the arithmetic sum of these two speeds.
10. Along the frictionless path you have chosen in question 8, the speed of the puck after receiving the kick
 1. is constant.
 2. continuously increases.
 3. continuously decreases.
 4. increases for a while and decreases thereafter.
 5. is constant for a while and decreases thereafter.
11. Along the frictionless path you have chosen in question 8, the main force(s) acting on the puck after receiving the kick is (are)
 1. a downward force of gravity.
 2. a downward force of gravity, and a horizontal force in the direction of motion.
 3. a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion.
 4. a downward force of gravity and an upward force exerted by the surface.
 5. none. (No forces act on the puck.)
12. A ball is fired by a cannon from the top of a cliff as shown below. Which of the paths 1–5 would the cannon ball most closely follow?



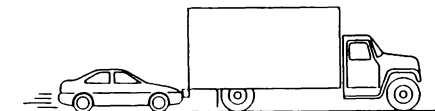
13. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are)
 1. a downward force of gravity along with a steadily decreasing upward force.
 2. a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the ball gets closer to Earth.
 3. an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only an almost constant downward force of gravity.
 4. an almost constant downward force of gravity only.
 5. none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the Earth.
14. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction.

As observed by a person standing on the ground and viewing the plane as in the figure below, which of the paths 1–5 would the bowling ball most closely follow after leaving the airplane?



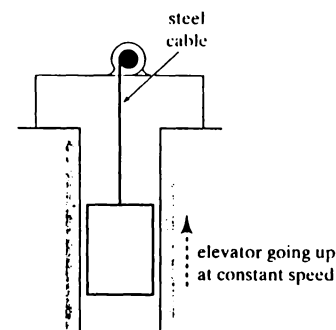
Use the statement and figure below to answer the next two questions (15 and 16).

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

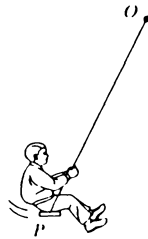


15. While the car, still pushing the truck, is speeding up to get up to cruising speed,
1. the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
 2. the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
 3. the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
 4. the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
 5. neither the car nor the truck exerts any force on the other. The truck is pushed forward simply because it is in the way of the car.
16. After the car reaches the constant cruising speed at which its driver wishes to push the truck,
1. the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
 2. the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
 3. the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
 4. the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
 5. neither the car nor the truck exerts any force on the other. The truck is pushed forward simply because it is in the way of the car.

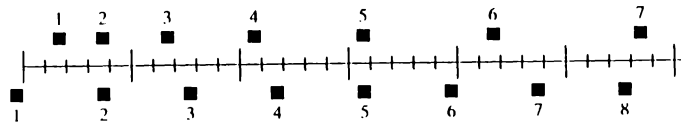
17. An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the following figure. All frictional effects are negligible. In this situation, forces on the elevator are such that
1. the upward force by the cable is greater than the downward force of gravity.
 2. the upward force by the cable is equal to the downward force of gravity.
 3. the upward force by the cable is smaller than the downward force of gravity.
 4. the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
 5. none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).



18. The following figure shows a boy swinging, starting at a point higher than P . Consider the following distinct forces:
- A. a downward force of gravity.
 - B. a force exerted by the rope pointing from P to O .
 - C. a force in the direction of the boy's motion.
 - D. a force pointing from O to P .
- Which of the above forces is (are) acting on the boy when he is at position P ?
1. A only
 2. A and B
 3. A and C
 4. A, B, and C
 5. A, C, and D

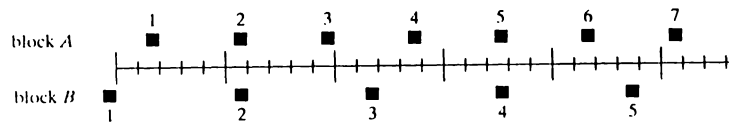


19. The positions of two blocks at successive 0.20-s time intervals are represented by the numbered squares in the following figure. The blocks are moving toward the right.



Do the blocks ever have the same speed?

1. No.
 2. Yes, at instant 2.
 3. Yes, at instant 5.
 4. Yes, at instants 2 and 5.
 5. Yes, at some time during the interval 3 to 4.
20. The positions of two blocks at successive 0.20-s time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



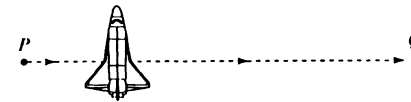
The accelerations of the blocks are related as follows:

1. The acceleration of *A* is greater than the acceleration of *B*.

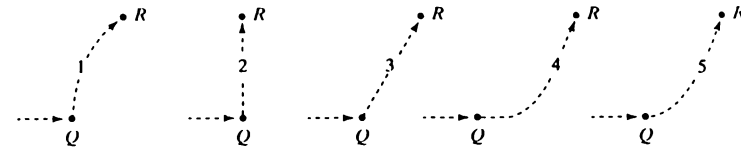
2. The acceleration of *A* equals the acceleration of *B*. Both accelerations are greater than zero.
3. The acceleration of *B* is greater than the acceleration of *A*.
4. The acceleration of *A* equals the acceleration of *B*. Both accelerations are zero.
5. Not enough information is given to answer the question.

Use the statement and figure below to answer the next four questions (21 through 24).

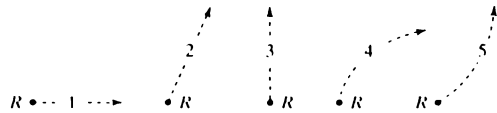
A spaceship drifts sideways in outer space from point *P* to point *Q* as shown below. The spaceship is subject to no outside forces. Starting at position *Q*, the spaceship's engine is turned on and produces a constant thrust (force on the spaceship) at right angles to the line *PQ*. The constant thrust is maintained until the spaceship reaches a point *R* in space.



21. Which of the paths 1–5 below best represents the path of the spaceship between points *Q* and *R*?



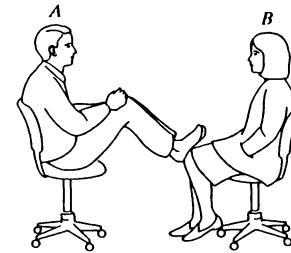
22. As the spaceship moves from point *Q* to point *R* its speed is
1. constant.
 2. continuously increasing.
 3. continuously decreasing.
 4. increasing for a while and constant thereafter.
 5. constant for a while and decreasing thereafter.
23. At point *R*, the spaceship's engine is turned off and the thrust immediately drops to zero. Which of the paths 1–5 will the spaceship follow beyond point *R*?



24. Beyond position R the speed of the spaceship is
1. constant.
 2. continuously increasing.
 3. continuously decreasing.
 4. increasing for a while and constant thereafter.
 5. constant for a while and decreasing thereafter.
25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed v_0 . The constant horizontal force applied by the woman
1. has the same magnitude as the weight of the box.
 2. is greater than the weight of the box.
 3. has the same magnitude as the total force that resists the motion of the box.
 4. is greater than the total force that resists the motion of the box.
 5. is greater than either the weight of the box or the total force that resists its motion.
26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves
1. with a constant speed that is double the speed v_0 in the previous question.
 2. with a constant speed that is greater than the speed v_0 in the previous question, but not necessarily twice as great.
 3. for a while with a speed that is constant and greater than the speed v_0 in the previous question, then with a speed that increases thereafter.
 4. for a while with an increasing speed, then with a constant speed thereafter.
 5. with a continuously increasing speed.
27. If the woman in question 25 suddenly stops applying a horizontal force to the block, then the block
1. immediately comes to a stop.
 2. continues moving at a constant speed for a while and then slows to a stop.

3. immediately starts slowing to a stop.
4. continues at a constant speed.
5. increases its speed for a while and then starts slowing to a stop.

28. In the following figure, student A has a mass of 75 kg and student B has a mass of 57 kg. They sit in identical office chairs facing each other. Student A places his bare feet on the knees of student B , as shown. Student A then suddenly pushes outward with his feet, causing both chairs to move.



During the push and while the students are still touching one another,

1. neither student exerts a force on the other.
 2. student A exerts a force on student B , but B does not exert any force on A .
 3. each student exerts a force on the other, but B exerts the larger force.
 4. each student exerts a force on the other, but A exerts the larger force.
 5. each student exerts the same amount of force on the other.
29. An empty office chair is at rest on a floor. Consider the following forces:
- A. a downward force of gravity.
 - B. an upward force exerted by the floor.
 - C. a net downward force exerted by the air.
- Which of the forces is (are) acting on the office chair?
1. A only
 2. A and B
 3. B and C
 4. A, B, and C
 5. None of the forces. (Since the chair is at rest, there are no forces acting upon it.)

30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court.

Consider the following forces:

- A. a downward force of gravity.
- B. a force by the "hit."
- C. a force exerted by the air.

Which of the above forces is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?

- 1. A only
- 2. A and B
- 3. A and C
- 4. B and C
- 5. A, B, and C

ANSWER KEY FOR FORCE CONCEPT INVENTORY

Note: Question number is followed by correct answer.

1.	3	11.	4	21.	5
2.	1	12.	2	22.	2
3.	3	13.	4	23.	2
4.	5	14.	4	24.	1
5.	2	15.	1	25.	3
6.	2	16.	1	26.	5
7.	2	17.	2	27.	3
8.	2	18.	2	28.	5
9.	5	19.	5	29.	2
10.	1	20.	4	30.	3

力學觀念測驗

* 下列題目均為單選題

1. 兩金屬球具相同體積，但其中一球的重量是另一球的兩倍。若將兩球同時從二樓陽台上放下，則兩球落地所須的時間為

1. 較重的球為令另一球所需時間的一半
2. 較輕的球為令另一球所需時間的一半
3. 兩球所需時間相同
4. 較重的球比令另一球所需時間少一些但相差不到一半
5. 較輕的球比令另一球所需時間少一些但相差不到一半

2. 承上題，若將此兩金屬球放在水平桌面上，離桌子邊緣一段距離，以相同的速度滾動後，並從桌子邊緣落到地面則

1. 兩球落地位置，到桌面邊緣的水平距離幾乎相等
2. 較重的球落地位置，到桌面邊緣的水平距離，約為另一球距離一半
3. 較輕的球落地位置，到桌面邊緣的水平距離，約為另一球距離一半
4. 較重的球落地位置離桌面邊緣比另一球來得近，但兩球距離相差不到一半
5. 較輕的球落地位置離桌面邊緣比另一球來得近，但兩球距離相差不到一半

3. 一粒石頭，從一樓屋頂掉落到地面上，在掉落過程中，

1. 石頭很快到達最高的速率，並保持此一速率下降
2. 石頭會逐漸加速，主要是因為石頭越

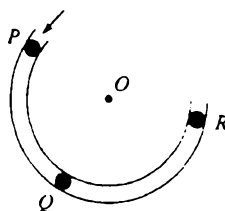
接近地面所受到的引力越大

3. 石頭會逐漸加速，因為石頭受到一幾乎固定的重力作用
4. 石頭會掉下來，是因為所有的東西都有自然的傾向落到地面
5. 石頭會掉下來，是因石頭同時受到重力及大氣壓力作用向下

4. 一輛大卡車與小轎車正面碰撞，則在碰撞過程

1. 卡車撞轎車的力，比轎車撞卡車的力來得大
2. 轎車撞卡車的力，比卡車撞轎車的力來得大
3. 兩車之間並沒有作用力，小轎車肢離破碎是因為擋到大車的路
4. 卡車施力作用於轎車，但轎車沒有施力於卡車
5. 卡車撞轎車的力，與轎車撞卡車的力一樣大

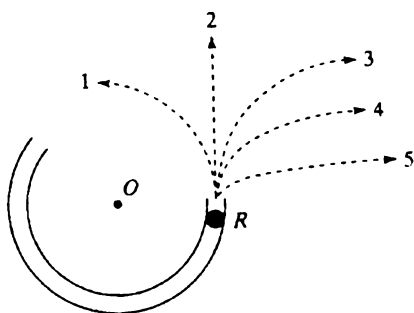
5. 一個有缺口之光滑環形管置於平滑之水平桌面，環形管的中心點為 O 點。從桌面垂直上方觀察，如圖所示。一球以一高速由 P 點射入管中並由 R 點射出。若不考慮空氣阻力，則在 Q 點時球受到下列那些力的作用？



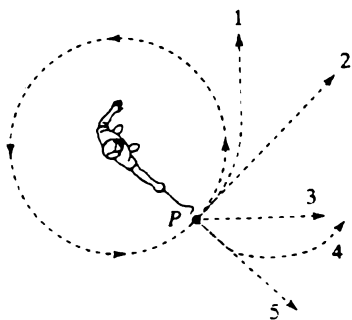
- A. 垂直向下的重力
 B. 環形管的作用力，由 Q 點朝 O 點方向
 C. 與運動同方向的作用力，
 D. 一作用力由 O 點朝 Q 點方向

1. 只有 A
2. 只有 A 和 B
3. 只有 A 和 C
4. A、B 和 C
5. A、C 和 D

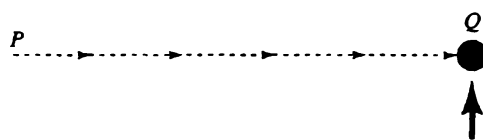
6. 承上題，當球由 R 點射出時，在無摩擦之光滑桌面運動，最可能是圖中 1-5 之那一軌跡？



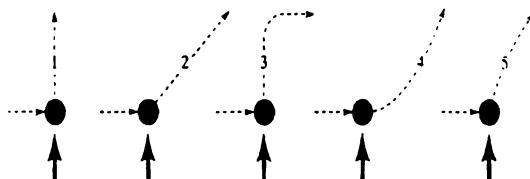
7. 一鐵球繫在一條弦上，並繞著水平面作圓周軌道旋轉，若在如圖所示之位置，弦突然斷裂則弦斷裂後球將沿圖上 1-5 之中那一軌跡運動？



- 請根據下列敘述及圖示回答第 8-11 題
- 下圖表示一曲棍球，在水平無摩擦之桌面上，以等速 v_0 由 P 點朝 Q 點方向滑動。當球到達 Q 點時，受到一球員以箭頭方向瞬間一擊。



8. 球在受球員一擊之後的軌跡應該是下列 1-5 選項之何者？



9. 承上題，球在受球員一擊之後，球的速率為

1. 和被球棒擊打之前的速率 v_0 相等
2. 等於球保持靜止時，受同一力擊打後的速率 v_k ，而與 v_0 無關
3. 等於 v_k 和 v_0 的算數大小之和
4. 必小於速率 v_k 或 v_0 。
5. 必大於 v_k 或 v_0 ，但小於兩速率大小之和

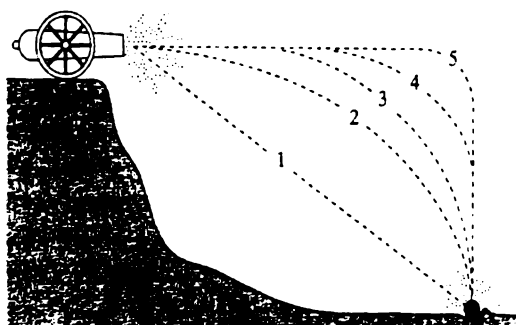
10. 承上題，球在受球員擊出之後，在無摩擦的地面上，球速的大小將會是

1. 保持不變
2. 逐漸增加
3. 逐漸減小
4. 先增加後再逐漸減小
5. 保持固定一會兒後逐漸減小

11. 承上題,球在被球員擊出之後,所受到的主要作用力為

1. 向下的重力及大氣壓力
2. 向下的重力及朝運動方向動量所造成的力
3. 向下的重力及地面所施向上的力,還有朝運動方向動量所造成的力
4. 向下的重力及地面所施向上的力
5. 球不受任何作用力

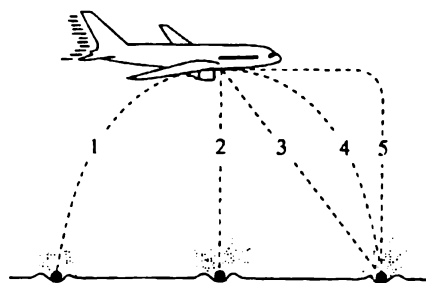
12. 如下圖,一球由大炮射擊出來後的軌跡,應最接近圖中 1-5 軌跡中的何項?



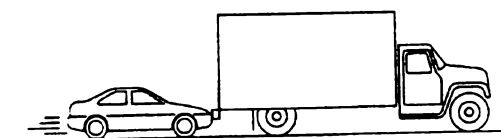
13. 一男孩將手上的鐵球垂直上拋,若不考慮空氣阻力,則鐵球在空中的過程所受的力為

1. 全部過程均受到向下的重力,以及一向上,且大小逐漸減弱的力,
2. 球在上升過程,受到一向上且逐漸減弱的力,而在下降過程中,球受到向下且逐漸增加的重力,因為此球逐漸靠近地面
3. 球離開男孩手之後受到一垂直向下的重力,以及一向上且逐漸減弱的力,一直到最高點。接著,球只受到一向下的且穩定的重力
4. 全部過程,球只受到一向下且穩定的重力
5. 以上皆非

14. 一保齡球,意外地從飛機上掉下,從地面上觀察球的運動,最可能的軌跡,應為下圖中 1-5 選項的那一項?



15. 一輛大卡車拋錨了,此卡車藉由後面的小轎車推動前進,如下圖。在小車持續推動大車,加速前進的過程中,

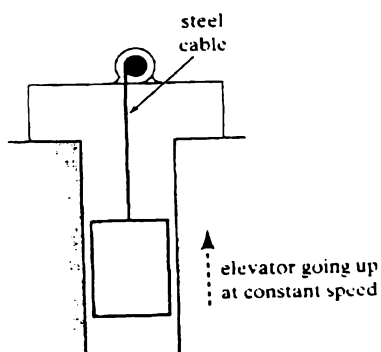


1. 轎車推卡車的力,與卡車頂轎車的力,大小相同
2. 轎車推卡車的力,小於卡車頂轎車的力
3. 轎車推卡車的力,大於卡車頂轎車的力
4. 小轎車引擎保持運轉,所以只有小轎車推大卡車的力,卡車沒有頂回轎車的力,因為卡車引擎沒有運轉
5. 兩車彼此均無作用力

16. 承上題,當兩車加速至設定時速後,保持等速前進的過程中

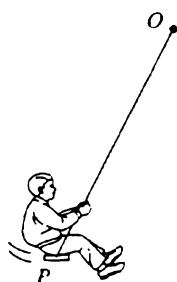
1. 轎車推卡車的力,與卡車頂轎車的力,大小相同
2. 轎車推卡車的力,小於卡車頂轎車的力
3. 轎車推卡車的力,大於卡車頂轎車的力
4. 小轎車引擎保持運轉,所以只有小轎車推大卡車的力,卡車沒有頂回轎車的力,因為卡車引擎沒有運轉
5. 兩車彼此均無作用力

17. 如圖所示,一電梯由鋼繩懸吊,並保持等速上升,假設空氣阻力微小至可以忽略不計。則在上升過程中,電梯受力情形為



1. 鋼繩上拉的力, 大於向下的重力
2. 鋼繩上拉的力, 等於向下的重力
3. 鋼繩上拉的力, 小於向下的重力
4. 鋼繩上拉的力, 大於向下的重力以及空氣下壓的力之和
5. 以上皆非, 電梯會上升是因為鋼繩變短, 而不是鋼繩施力給電梯

18. 如下圖, 一男孩由一高於 P 點之位置開始盪秋千。則到達 P 點時男孩受到下列那些力作用?



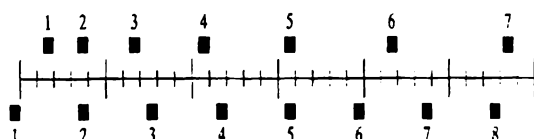
- A. 向下的重力
 - B. 繩子的作用力, 方向由 P 向 O
 - C. 一作用力延著男孩運動的方向
 - D. 一作用力, 方向由 O 向 P
1. 只有 A
 2. 只有 A, B
 3. 只有 A, C

4. 只有 A, B, C

5. 只有 A, C, D

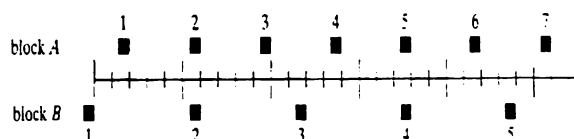
19. 兩木塊, 在連續的 0.20 秒時間內, 朝右方運動。其位置如下圖所示, 則

兩木塊是否在那一(或那些)位置具有相同的速度?



1. 沒有任何位置具有相同的速度
2. 在 2 的瞬間, 兩木塊具有相同的速度
3. 在 5 的瞬間, 兩木塊具有相同的速度
4. 在 2 和 5 兩瞬間, 兩木塊均具有相同的速度
5. 在 3 到 4 之間的某一瞬間, 兩木塊具有相同的速度

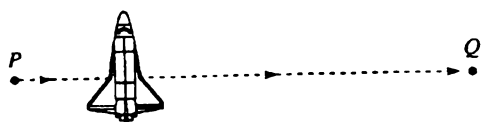
20. 兩木塊 A 及 B, 在連續的 0.20 秒時間內朝右方運動, 其位置如下圖所示, 則有關木塊加速度的敘述, 下列何項正確?



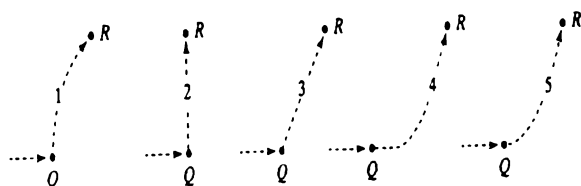
1. 木塊 A 的加速度大於木塊 B
2. 木塊 A 的加速度等於木塊 B, 且兩者加速度均大於零
3. 木塊 A 的加速度小於木塊 B
4. 兩木塊的加速度均為零
5. 資料不足, 所以無法回答

- 請根據下列敘述及圖示回答第 21-24 題

- 一艘火箭,在外太空且不受外力作用下,由 P 點橫向漂行到 Q 點。到達 Q 點時,火箭引擎開始啓動,並產生一與 PQ 方向相垂直的推力,一直到達 R 點時,引擎再度關閉。



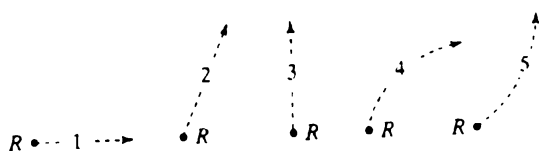
21. 下列 1-5 選項,何者最能描述出火箭由 Q 點到 R 點的軌跡?



22. 承上題,火箭由 Q 點到 R 點的過程中,其速率大小

1. 保持常數
2. 逐漸增加
3. 逐漸減小
4. 先增加後,保持常數
5. 先保持常數後,逐漸減小

23. 承上題,火箭在 R 點時關掉引擎。則其在 R 點之後的軌跡,應該為 1-5 之中的何項?



24. 承上題,火箭在 R 點之後的速率大小為

1. 保持常數
2. 逐漸增加
3. 逐漸減小

4. 先增加後,保持常數
5. 先保持常數後,逐漸減小

25. 某人施一固定的力於地板上之木箱,使木箱在水平地板上保持等速度 v_0 前進。則此人對木箱之作用力必須

1. 等於木箱之重量的大小
2. 大於木箱之重量的大小
3. 等於木箱所受之摩擦阻力的大小
4. 大於木箱所受之摩擦阻力的大小
5. 大於木箱之重量或木箱所受之摩擦阻力的大小

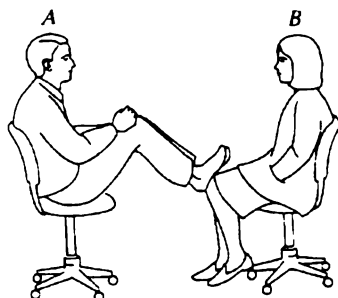
26. 承上題,若此人對同一木箱之施力變為原施力之兩倍,則木箱之運動將如何?

1. 變為 $2v_0$ 之速率,等速前進
2. 保持等速,且速率大於 v_0 ,但不一定達到 $2v_0$ 。
3. 先保持一段等速運動,其速率大於 v_0 ,之後速率逐漸增加
4. 保持一段時間的加速前進,之後保持等速運動
5. 持續地保持加速運動

27. 承上題,若此人作用於木箱的推力突然停止,則從推力停止的瞬間開始,木箱將會

1. 立即停止運動
2. 保持一短時間的等速前進後,逐漸減速至停止
3. 立即開始減速至停止
4. 繼續保持等速前進
5. 保持一短時間的加速前進後,逐漸減速至停止

28. 兩學生 A 和 B，學生 A 質量是 75 公斤，學生 B 是 57 公斤，兩人各坐在相同的辦公椅上(含輪子)。如圖所示，學生 A 以雙腳踏在學生 B 的膝蓋上，若學生 A 突然將其雙腳往前踏出，使兩人開始運動。則在學生 A 踏出，且兩人保持接觸的過程中，



1. 兩人均不受到對方的作用力
2. 學生 A 施力給學生 B,但學生 B 沒有施力給學生 A
3. 兩人均受到對方的作用力,但學生 B 作用在學生 A 身上的力較大
4. 兩人均受到對方的作用力,但學生 A 作用在學生 B 身上的力較大
5. 兩人均施給對方一樣大的作用力

29. 一張空的辦公椅(含輪子)靜止置於地面上，則椅子受下列那些力作用？

- A. 向下的重力，
- B. 地板的作用力向上
- C. 空氣造成的淨力向下

1. 只有 A
2. 只有 A，B
3. 只有 B，C
4. A，B，C 三力均有作用
5. 完全不受力，因為椅子保持靜止

30. 在強風下，一網球球員將球打到對方的球場，則球離開球拍的接觸後，到落地前的過程中，球受到下列那些力的作用？

- A. 向下方向的重力
- B. 球拍擊球的力量

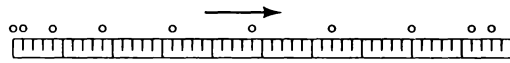
C. 空氣的作用力

1. 只有 A
2. 只有 A，B
3. 只有 A，C
4. 只有 B，C
5. A，B，C 三力均有作用

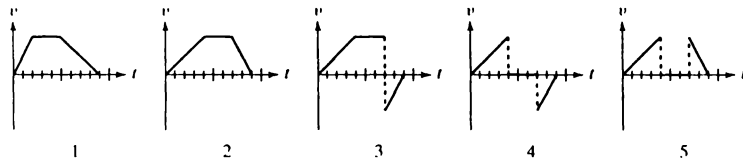
Appendix C2: Mechanics Baseline Test

Refer to the figure below when answering the first two questions (1 and 2).

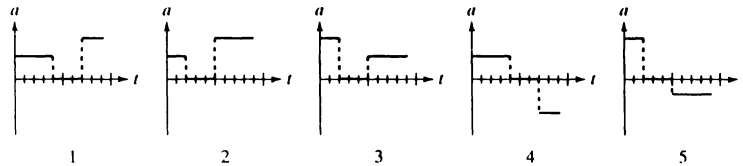
This diagram represents a multiframe photograph of an object moving along a horizontal surface. The positions indicated in the diagram are separated by equal time intervals. The first flash occurred just as the object started to move and the last just as it came to rest.



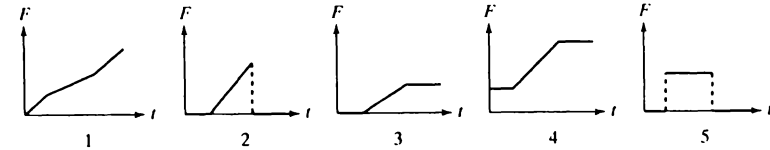
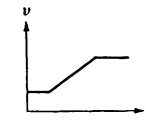
1. Which of the graphs 1–5 below best represents the object's velocity as a function of time?



2. Which of the graphs 1–5 below best represents the object's acceleration as a function of time?

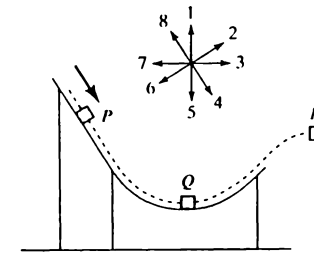


3. The velocity of an object as a function of time is shown in the following graph. Which of the graphs 1–5 best represents the net-force vs. time re-



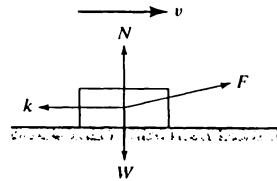
Refer to the following figure when answering the next three questions (4 through 6).

This diagram depicts a block sliding along a frictionless ramp. The eight numbered arrows in the diagram represent directions to be referred to when answering questions 4–6.

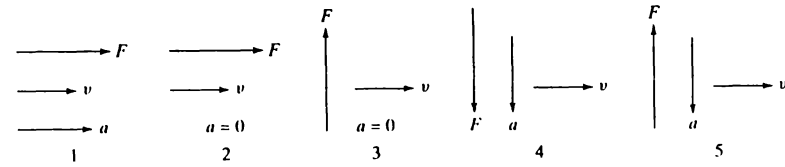
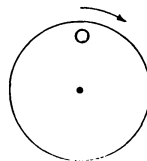


4. The direction of the acceleration of the block, when in position *P*, is best represented by which of the arrows in the diagram?
1. Arrow 1
 2. Arrow 2
 2. Arrow 4
 4. Arrow 5
 5. None of the arrows, the acceleration is zero.
5. The direction of the acceleration of the block when in position *Q* is best represented by which of the arrows in the diagram?
1. Arrow 1

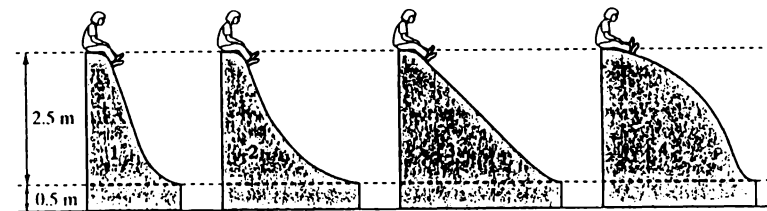
3. Arrow 5
 4. Arrow 7
 5. None of the arrows, the acceleration is zero.
6. The direction of the acceleration of the block (after leaving the ramp) at position *R* is best represented by which of the arrows in the diagram?
1. Arrow 2
 2. Arrow 3
 3. Arrow 5
 4. Arrow 6
 5. None of the arrows, the acceleration is zero.
7. A person pulls a block across a rough horizontal surface at a *constant speed* by applying a force *F*. The arrows in the diagram below correctly indicate the directions, but not necessarily the magnitudes of the various forces on the block. Which of the following relations among the force magnitudes *W*, *k*, *N*, and *F* *must be true*?



1. $F = k$ and $N = W$
 2. $F = k$ and $N > W$
 3. $F > k$ and $N < W$
 4. $F < k$ and $N = W$
 5. None of the above choices
8. A small metal cylinder rests on a circular turntable, rotating at a constant speed as illustrated in the diagram below. Which of the sets of vectors 1–5 below best describes the velocity, acceleration, and net force acting on the cylinder at the point indicated in the diagram?



9. Suppose that the metal cylinder in the last problem has a mass of 0.10 kg and that the coefficient of static friction between the surface and the cylinder is 0.12. If the cylinder is 0.20 m from the center of the turntable, at what maximum speed *v* can the cylinder move along its circular path without slipping off the turntable?
1. $0 < v \leq 0.5$ m/s.
 2. $0.5 < v \leq 1.0$ m/s.
 3. $1.0 < v \leq 1.5$ m/s.
 4. $1.5 < v \leq 2.0$ m/s.
 5. $2.0 < v \leq 2.5$ m/s.
10. A young girl wishes to select one of the *frictionless* playground slides illustrated below to give her the greatest possible speed when she reaches the bottom of the slide.

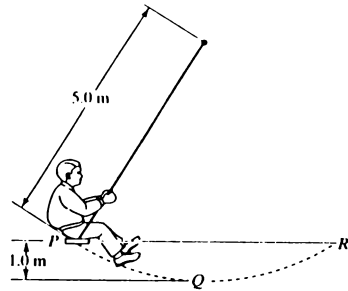


Which of the slides illustrated in the diagram above should she choose?

1. Slide 1
2. Slide 2
3. Slide 3
4. Slide 4
5. It doesn't matter, her speed would be the same for each slide.

Refer to the figure below when answering the next two questions (11 and 12).

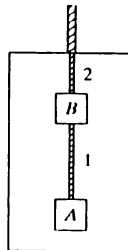
P and R mark the highest and Q the lowest positions of a 50.0-kg boy swinging as illustrated in the following figure.



11. What is the boy's speed at point Q ?
 1. 2.5 m/s
 2. 7.5 m/s
 3. 10.0 m/s
 4. 12.5 m/s
 5. None of the above.
12. What is the tension in the rope at point Q ?
 1. 250 N
 2. 525 N
 3. 7×10^2 N
 4. 1.1×10^3 N
 5. None of the above.

Refer to the figure below when answering the next two questions (13 and 14).

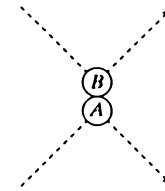
Blocks A and B , each with a mass of 1.0 kg, are hung from the ceiling of an elevator by ropes 1 and 2.



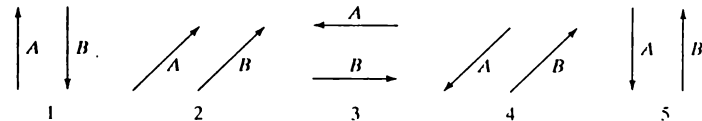
13. What is the force exerted by rope 1 on block A when the elevator is traveling upward at a constant speed of 2.0 m/s?
 1. 2 N
 2. 10 N
 3. 12 N
 4. 20 N
 5. 22 N
14. What is the force exerted by rope 1 on block B when the elevator is stationary?
 1. 2 N
 2. 10 N
 3. 12 N
 4. 20 N
 5. 22 N

Refer to the following figure when answering the next two questions (15 and 16).

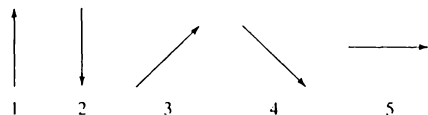
The figure below depicts the paths of two colliding steel balls, A and B .



15. Which set of arrows best represents the direction of the change in momentum of each ball?



16. Which arrow best represents the impulse applied to ball *B* by ball *A* during the collision?



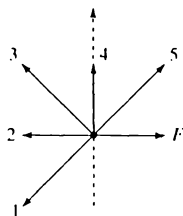
17. A car has a maximum acceleration of 3.0 m/s^2 . What would its maximum acceleration be while towing a second car twice its mass?

1. 2.5 m/s^2
2. 2.0 m/s^2
3. 1.5 m/s^2
4. 1.0 m/s^2
5. 0.5 m/s^2

18. A woman weighing $6.0 \times 10^2 \text{ N}$ is riding an elevator from the 1st to the 6th floor. As the elevator approaches the 6th floor, it decreases its upward speed from 8.0 to 2.0 m/s in 3.0 s . What is the average force exerted by the elevator floor on the woman during this 3.0-s interval?

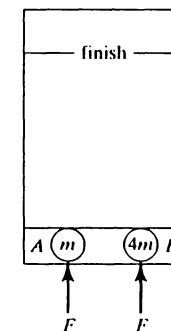
1. 120 N
2. 480 N
3. 600 N
4. 720 N
5. 1200 N

19. The diagram below depicts a hockey puck moving across a *horizontal, frictionless* surface in the direction of the dashed arrow. A constant force *F*, shown in the diagram, is acting on the puck. For the puck to experience a net force *in the direction of the dashed arrow*, another force must be acting in which of the directions 1–5 below?



Refer to the following figure when answering the next three questions (20 through 22).

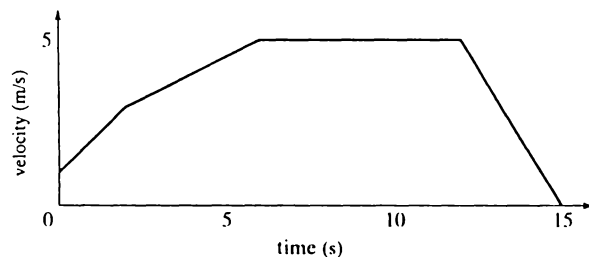
The diagram below depicts two pucks on a frictionless table. Puck *B* is four times as massive as puck *A*. Starting from rest, the pucks are pushed across the table by two *equal* forces.



20. Which puck has the greater kinetic energy upon reaching the finish line?
1. Puck *A*
 2. Puck *B*
 3. They both have the same amount of kinetic energy.
 4. too little information to answer
21. Which puck reaches the finish line first?
1. Puck *A*
 2. Puck *B*
 3. They both reach the finish line at the same time.
 4. too little information to answer
22. Which puck has the greater momentum upon reaching the finish line?
1. Puck *A*
 2. Puck *B*
 3. They both have the same momentum.
 4. too little information to answer

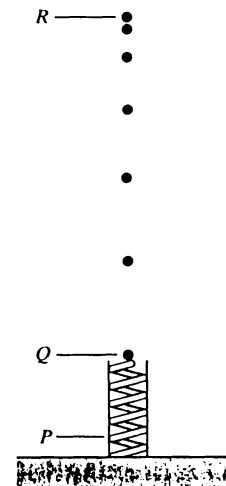
Refer to the following figure when answering the next three questions (23 through 25).

The graph below represents the motion of an object moving in one dimension.



23. What was the object's average acceleration between $t = 0$ s and $t = 6.0$ s?
1. 3.0 m/s^2
 2. 1.5 m/s^2
 3. 0.83 m/s^2
 4. 0.67 m/s^2
 5. none of the above
24. How far did the object travel between $t = 0$ and $t = 6.0$ s?
1. 20.0 m
 2. 8.0 m
 3. 6.0 m
 4. 1.5 m
 5. none of the above
25. What was the average speed of the object for the first 6.0 s?
1. 3.3 m/s
 2. 3.0 m/s
 3. 1.8 m/s
 4. 1.3 m/s
 5. none of the above

26. The figure below represents a multiframe photograph of a small ball being shot straight up by a spring. The spring, with the ball atop, was initially compressed to the point marked P and released. The ball left the spring at the point marked Q , and reached its highest point at the point marked R .



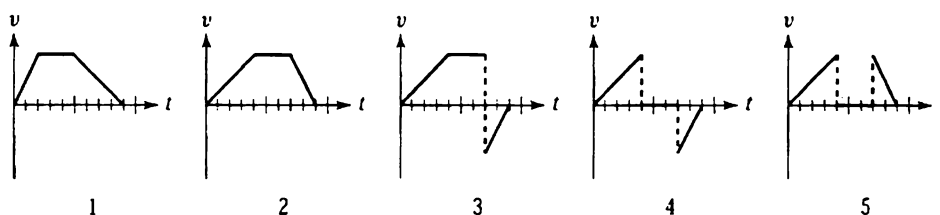
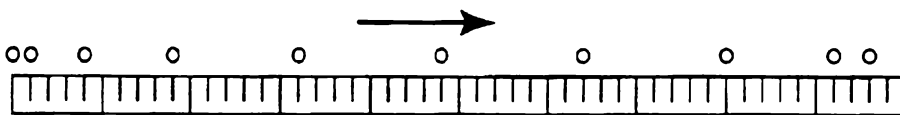
Assuming that the air resistance was negligible:

1. The acceleration of the ball was greatest just before it reached point Q (still in contact with the spring).
2. The acceleration of the ball was decreasing on its way from point Q to point R .
3. The acceleration of the ball was zero at point R .
4. All of the above responses are correct.
5. The acceleration of the ball was the same for all points in its trajectory from points Q to R .

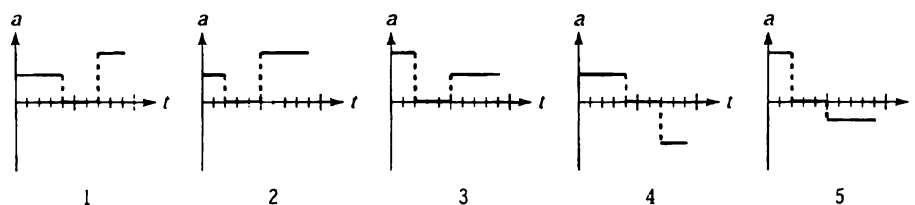
力學能力測驗

* 下列所有題目均為單選題，且假設重力加速度 $g = 10 \text{ m/s}^2$

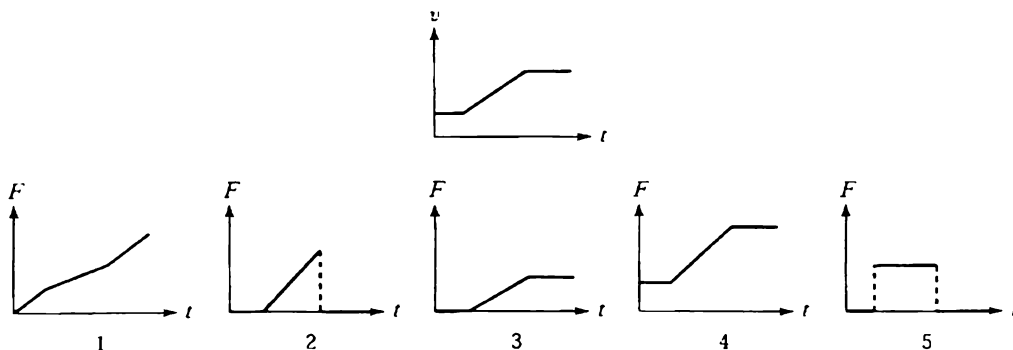
1 下圖表示一物體沿直線運動，在相等時間間隔的位置。第一點為物體從靜止開始運動的位置，下列 1-5 選項，何者可代表此物體之速度對時間之關係圖？



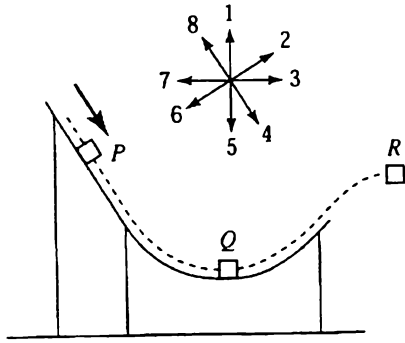
2. 承上題，下列選項中，何者最適合描述此物體之加速度對時間之關係圖？



3. 一物體，其速度對時間之關係如下圖所示，則下列選項何者最適合描述此物體所受到的淨力對時間之關係圖？

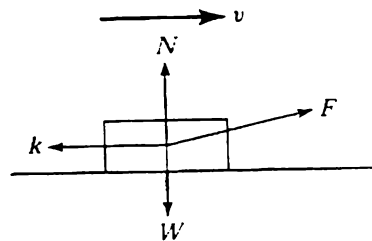


一木塊從下圖中之曲面滑下，假設曲面光滑無摩擦，請根據圖中箭頭的數字回答下列 4-6 題

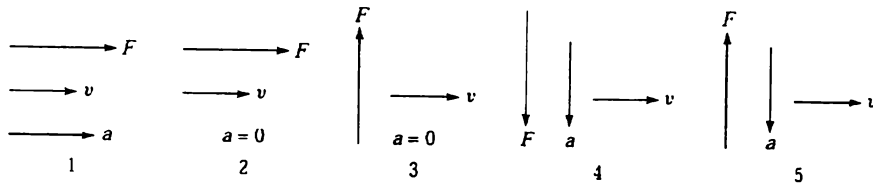
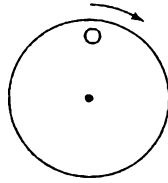


4. 當木塊到達 P 點時，其加速度的方向可能是那一箭頭方向？
- | | | |
|---------|---------|-------------------------|
| 1. 箭頭 1 | 3. 箭頭 4 | 5. 以上皆非，在 P 點時
加速度為零 |
| 2. 箭頭 2 | 4. 箭頭 5 | |
5. 承上題，當木塊到達 Q 點時，其加速度的方向可能是那一箭頭方向？
- | | | |
|---------|---------|-------------------------|
| 1. 箭頭 1 | 3. 箭頭 5 | 5. 以上皆非，在 Q 點時
加速度為零 |
| 2. 箭頭 3 | 4. 箭頭 7 | |
6. 承上題，當木塊脫離曲面到達 R 點時，其加速度的方向可能是那一箭頭方向？
- | | | |
|---------|---------|-------------------------|
| 1. 箭頭 2 | 3. 箭頭 5 | 5. 以上皆非，在 R 點時
加速度為零 |
| 2. 箭頭 3 | 4. 箭頭 6 | |

7. 一個人施一力 F 拉動木塊，使得木塊保持等速率運動。右圖表示木塊所受所有作用力的方向，但不代表各力之間的大小關係。則有關各力間的大小關係，下列敘述何者正確？



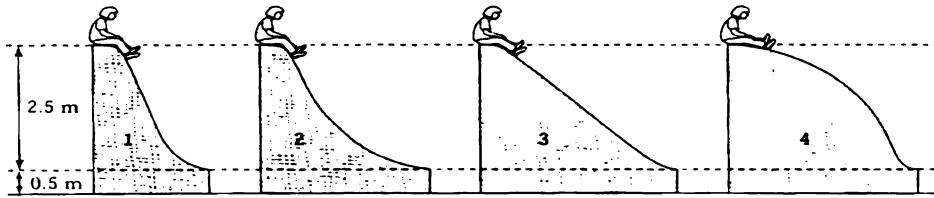
- | | | |
|----------------------|----------------------|---------|
| 1. $F = k$ 且 $N = W$ | 3. $F > k$ 且 $N < W$ | 5. 以上皆非 |
| 2. $F = k$ 且 $N > W$ | 4. $F < k$ 且 $N = W$ | |
8. 一金屬圓柱保持固定於等速率旋轉之轉盤中。轉盤為一水平面，由上方垂直向下觀察為下圖所示。則金屬圓柱在圖上位置時之速度、加速度、及其所受之淨力方向，下列何者正確？



9. 承上題，假設金屬圓柱之質量為 0.10 kg ，圓柱與桌面之靜摩擦係數為 0.12 ，且圓柱距轉盤中心為 0.20 m 。為維持此圓柱不滑離轉盤，圓柱之轉動速率上限應在下列選項之那一範圍內？

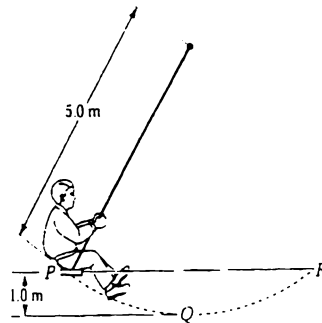
- | | | |
|-----------------------------------|-----------------------------------|-----------------------------------|
| 1. $0 < v \leq 0.5 \text{ m/s}$ | 3. $1.0 < v \leq 1.5 \text{ m/s}$ | 5. $2.0 < v \leq 2.5 \text{ m/s}$ |
| 2. $0.5 < v \leq 1.0 \text{ m/s}$ | 4. $1.5 < v \leq 2.0 \text{ m/s}$ | |

10. 一女孩，由下列四個不同滑梯滑下。假設四個滑梯均無摩擦，則女孩經由那一滑梯，可得最大速率落地？



- | | | |
|---------|---------|---------------------|
| 1. 滑梯 1 | 3. 滑梯 3 | 5. 女孩經由每一滑梯之落地速率均相同 |
| 2. 滑梯 2 | 4. 滑梯 4 | |

11. 如圖所示，一男孩 50 kg 在盪鞦韆。過程中 P 點與 R 點為鞦韆之最高點，Q 點為其最低點，則男孩在 Q 點時之速率應為

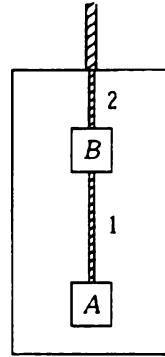


- | | | |
|----------------------|-----------------------|---------|
| 1. 2.5 m/s | 3. 10.0 m/s | 5. 以上皆非 |
| 2. 7.5 m/s | 4. 12.5 m/s | |

12. 承上題，當鞦韆盪到 Q 點時繩索的張力為

1. 250 N 3. 7×10^2 N 5. 以上皆非
2. 525 N 4. 1.1×10^3 N

13. 兩木塊 A 與 B，質量均為 1.0kg 由兩條繩索 1 與 2 懸吊於電梯之天花板，如圖所示。則當電梯正在以 2.0 m/s 之速率等速上升時木塊 A 受到繩索 1 之作用力為何？

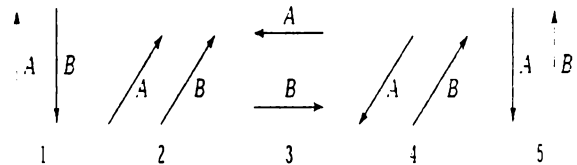
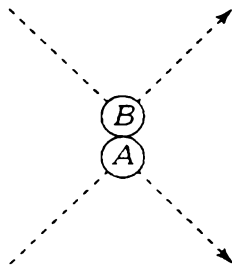


1. 2 N 3. 12 N 5. 22 N
2. 10 N 4. 20 N

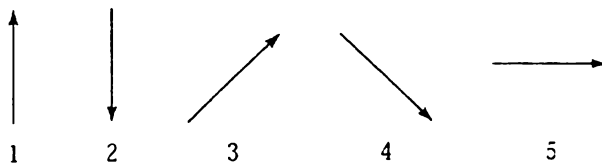
14. 承上題，當木塊保持靜止時，繩索 1 作用在木塊 B 上之作用力為何？

1. 2 N 3. 12 N 5. 22 N
2. 10 N 4. 20 N

15. 下圖描述兩鐵球 A 與 B 碰撞前後之軌跡，則下列何項可正確描述出兩球在碰撞過程的動量變化？

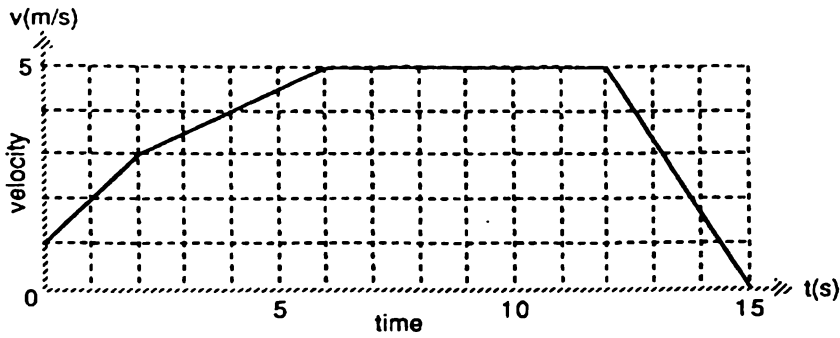


16. 承上題，下列那一箭頭方向最能描述出兩球在碰撞過程中 A 球對 B 球所作用的衝量？



17. 甲車之最大加速度為 3.0 m/s^2 。若用甲車來拖乙車，且乙車之質量為甲車之 2 倍，則此時兩車可得之最大加速度為何？

1. 2.5 m/s^2 3. 1.5 m/s^2 5. 0.5 m/s^2
2. 2.0 m/s^2 4. 1.0 m/s^2



23. 上圖描述一物體在直線上運動過程之速度對時間的關係圖，則此物體在 0 秒到 6.0 秒的時間間隔內，其平均加速度為何？

1. 3.0 m/s^2 3. 0.83 m/s^2 5. 以上皆非
2. 1.5 m/s^2 4. 0.67 m/s^2

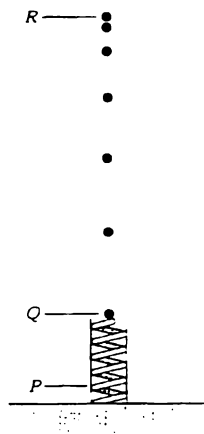
24. 承上題，此物體在 0 秒到 6.0 秒的時間間隔內，共移動多少距離？

1. 20.0 m 3. 6.0 m 5. 以上皆非
2. 8.0 m 4. 1.5 m

25. 承上題，此物體在最初的 6.0 秒時間內平均速率為何？

1. 3.3 m/s 3. 1.8 m/s 5. 以上皆非
2. 3.0 m/s 4. 1.3 m/s

26. 根據右圖，一球置於彈簧上，並被下壓至 P 點後釋放。球彈升至 Q 點後開始離開彈簧，並在 R 點抵達其最高位置。右圖表示球在相同時間間隔的位置，若忽略空氣阻力，下列敘述何項正確？



1. 球在 Q 點(仍與彈簧保持接觸)時加速度最大
2. 球的加速度在 Q 點到 R 點過程中逐漸減小
3. 球在 R 點時之加速度為零
4. 以上三項敘述均正確
5. 球的加速度在 Q 點到 R 點之過程中，保持定值

Appendix D1: Unit one

Unit 1: pulley

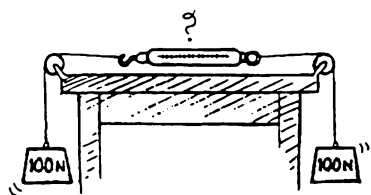
- a. fill in the questionnaires (15 min)
- b. explain the intervention teaching (5 min)
- c. organize physics quantity & principles (5 min)
- d. pulley: 4 questions (15 min) , monkey in the mirror (5 min), archery (5 min)

II. Summary:

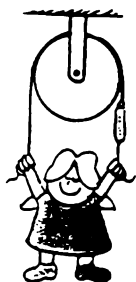
1. free force diagram
2. definition of tension
3. Newton's 2nd Law
4. Newton's 3rd Law
5. Definition of torque
6. difference between force and torque

Assignment: 1. complete the quantity & principle (need to read the text)

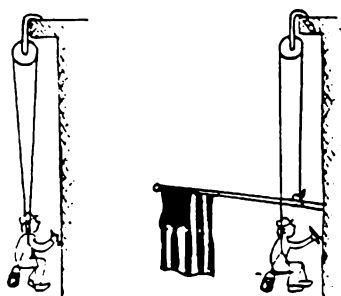
2. challenging questions: Stopping distance
3. record your study time



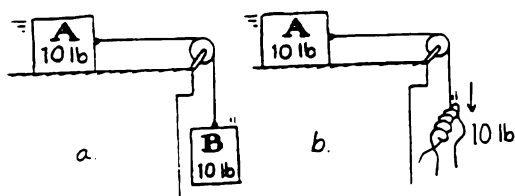
1. 彈簧秤上的讀數是多少?



2. 若小女孩的質量為 30 kg，(a) 則彈簧秤上的讀數是多少？ (b) 滑輪兩邊的繩子張力是否相等？ (c) 張力各是多少？



3. 油漆工人體重 700 牛頓，則 (a) 左右兩圖的繩子張力是否相等？ (b) 左右兩圖的繩子容忍的張力上限各是多少？



4. (a) a, b 兩圖中，木塊 A 的加速度是否相等？ (b) 若不相等，則手施的力量應為多少才能使兩圖中木塊 A 的加速度相等？

5. 猴子與鏡子

6. crazy pulley

Appendix D2: Unit two

Unit 2 Driving safety

I. content

- a. give score of pre-test/respond to the survey in unit 1 (5 min)
- b. complete the outlines & give hand-out (5 min)
- c. stopping distance (5-10 min)
- d. running a yellow light (10 min)
- e. turn or stop (10 min)
- f. break & anti-break system (5 min)

II. Summary of physics theories:

1. linear kinematics
2. Newton's 2nd Law
3. frictional force
4. centripetal force
5. work & energy conservation

III. Assignment:

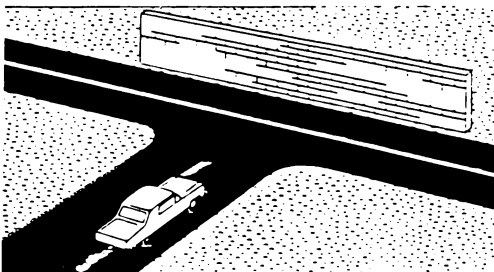
1. review summary
2. practice problem solving: prob. 3.31 (p.75), Ex 5.5 (p.119), prob. 5.23 (p.137),
prob. 6.26 (p.162)
3. IQ challenge problem: friction in drag racing

- *Next topic: sports & stunts*

1. 煞車距離與車速

2. 在十字路口前看到黃燈，該煞車或加速前進呢？試根據下列數據，討論可能的結論。

yellow light duration $t = 2 \text{ sec}$ width of the street $w = 30 \text{ ft}$
 car speed $v = 30 \text{ ft/sec} (= 32 \text{ km/hr})$ acceleration $a = \pm 10 \text{ ft/s}^2$



3. 如圖，高速行駛的車子為避免撞牆，應該直接煞車或是轉彎？何者較可能避免大災難？

Friction in drag racing

In drag races there are two measurements of interest: the final speed and the total elapsed time on a quarter-mile course. To help gain traction, a sticky fluid is poured under the rear wheels before the "go" light, but apparently the track's friction really affects only the elapsed time and has little influence on the final speed. Why?

4. 最大加速度 與 最大速度

Appendix D3: Unit three

Unit 3: Sports & Stunts

I. Content

- a. Timing sand (Demo) (10 min)
- b. Runner, swimmer/ in court /rubber bullet (20 min)
- c. Sledge (OHP) (15 min)
- d. Reading “The first Taiwanese satellite” & raising the questions (group discussion)
(10 min)

II. Summary of physics theories:

1. collision, elastic & inelastic
2. momentum conservation/ energy loss
3. Newton’s 2nd law (relation of force & impulse)
4. Newton’s 3rd Law

- Next topic: Satellites

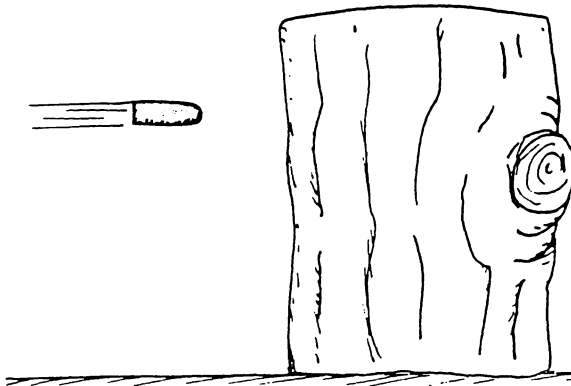
1. 沙漏的重量



2. 五公斤的花盆從架上掉下來，砸到一婦女，能否求出婦女所受的撞擊力為多少？



3. 一賽跑選手跑步過程中，選手前進與地面後退的動量是否相等？動能是否相等？
若考慮游泳者與泳池中的水，兩者動量是否相等？動能是否相等？



4. 一橡膠子彈與鋁製子彈(質量相等)，射向木塊，何種子彈較有可能推倒木塊？何種子彈較有可能破壞木塊？

5. 大銀頭與釘床

Appendix D4: Unit four

Unit 4 Leave the Earth: Satellite

- a. Launching position (presentation during the break) (5 min)
- b. Geo-stationary (communication)/ Polar satellite (spy, forecast) (10 min)
- c. spy satellite over Moscow (5 min)
- d. Calculation of speed, period vs. different distances/ F_g of shuttle (weightless) (15 min)
- f. *escaping speed, gravitation assist, voyager (10 min)

- ***Summary of physics theories:***

1. kinematics of circular motion
2. Newton's Universal Law of Gravity
3. energy conservation /gravitational potential energy
4. Kepler's Law

- ***Assignment:***

1. review summary
2. Problem-solving: Ex. 11.11(P.327), Ex 11.13 (P. 327)
3. IQ challenge problem:

1. Launching location 發射地點的選擇

2. Satellite: 人造衛星

Geostationary 同步衛星

Polar (南北極衛星)

3. 計算 (a) 同步衛星的高度，(b) 高度為 800km 的 polar satellite 的週期，(c) 同步衛星之總力學能($M_e = 6 \times 10^{24} \text{kg}$, $R_e = 6380 \text{ Km}$, $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$)

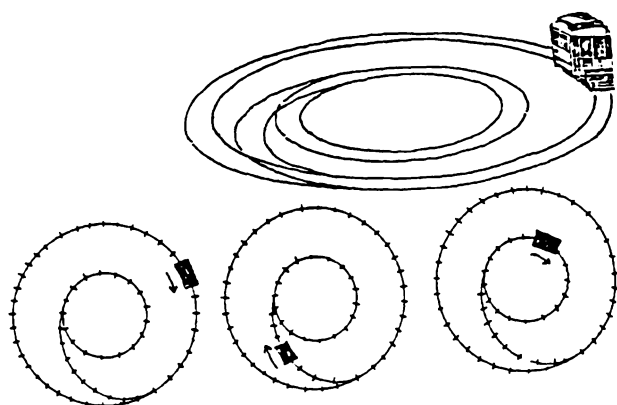
4. 太空梭內的人是否受重力?

5. 太空梭之繞行速率(rotational speed)? 脫離速率 (escape speed)?

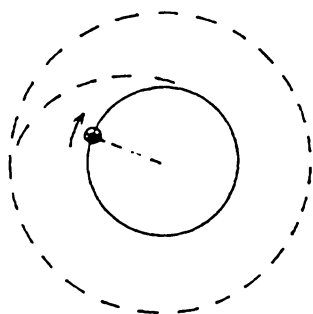


1. 人造衛星受空氣阻力的影響，軌道半徑將逐漸減小，則其速率將

a.) 逐漸增加 ， b.) 逐漸減小 ， c.) 不變



2. 軌道列車沿螺旋軌道滑行（無動力及摩擦），當軌道半徑逐漸減小則其速率將 a.) 逐漸增加 ， b.) 逐漸減小 ， c.) 不變



3. 繫在繩上旋轉的球 若繩子逐漸縮短則球之速率將 a.) 逐漸增加 ， b.) 逐漸減小 c.) 不變

(畫出力圖)

今日重點

1. 圓周運動 (circular motion/ Newton's second law) p.67-69, p. 115-122
2. 脫離速率 (escape speed) p.316-318
3. 能量與衛星運動 (energy conservation in planetary & satellite motion) p. 313-316
4. 力圖 (free-body diagram) p.94-96

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