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An Exploration of Senior High School Student Learning in Biology in Taiwan

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Abstract

This thesis explores senior high school student learning in biology in Taiwan. The Confucian-heritage culture and beliefs associated with high stakes examinations influences the learning context in biology. There is a considerable body of international research on teaching and learning in senior high biology. There appears to be limited research on student and teacher views of learning in biology in this context. A social constructivist view of learning underpins this study. Using an interpretive paradigm, this study explores student and teacher perceptions of student learning experiences in senior high school biology. There are three phases in this study. In the first phase, Grade 11 and Grade 12 students and teacher perceptions of the existing teaching and learning situation in biology was explored. In the second phase, an intervention was designed and implemented for Grade 12 students. In the third phase, the intervention was evaluated.

The findings of this study indicate that most students take biology to increase their options for entering tertiary education. Noticeably, they were using learning approaches that they most disliked to increase their biology marks. Most of them considered the current biology classes were very effective in coping with the major examination, but the teaching was monotonous and teaching content as seemingly unrelated to real life. The teachers perceived that student learning was passive, which contributed to the teachers feeling of exhaustion. Qualitative and quantitative data indicated that both the students and teachers were dissatisfied with the current teaching and learning situation. A more interactive teaching and learning approach and more student responsibility in investigations were suggested by the respondents.

An intervention programme based on a social constructivist view of learning, including interactive teaching and open investigation, was designed and implemented. The intervention (70% lecture classes and 30% experiment classes) problematised the traditional lesson structure (90% lecture classes and 10% experiment classes) of senior biology in Taiwan, seeking a more cohesive

and integrated overall structure for learning biology. Evaluation of the intervention programme suggested that through student-teacher and student-student interactions student conceptual and procedural understanding of biology was facilitated and their attitudes towards learning were enhanced. A few of the students could not accept the intervention as it conflicted with their view of learning in an examination culture. The implications of this research are that more teacher-student and peer interactions and open-ended investigations can lead to enhanced learning in biology in Taiwan for most senior high school students. Social constructivist approaches to teaching and learning are viable in a Taiwanese biology classroom context. The study also showed the potential for open investigations in this context.

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Chapter 1

Introduction

1.1 Introduction

The fact that Taiwanese students perform well in international standardized academic achievement tests has attracted special attention from education researchers (Budge, 1996; Stevenson, Lummis, Lee, & Stigler 1992; Stevenson, Chen, Lee, & Stigler 1993; Wu, 1997). In science education, numerous reasons have been offered to explain Taiwanese student success, but there has been little discussion of whether the tests are effective indicators of all scientific abilities, or whether success is tightly associated with what might be considered good learning. As a senior high school teacher for many years, the researcher found that the majority of the students were learning passively and the atmosphere of the class was not supportive for interactions. Similarly, laboratory work seemed to stimulate student thinking rarely. There is limited research about Taiwan's senior high school student learning in biology, especially in/through laboratory experiments. Some of the articles related to the biology laboratory do not place any emphasis on the nature of investigations or student learning outcomes from doing investigations, but on the other aspects; for example, the relationship between a laboratory learning environment and student attitudes toward science and academic achievement (Su & Huang, 1999). In Taiwan, typically, there are recipe-type experiments in senior high school biology laboratories and little attempts by teachers to allow students to have more autonomy and to do their own investigations. To date, no research has been reported on 'open' investigations in senior high school biology laboratory work in Taiwan. Confronted by rapid change in the twenty-first century, old ways of education designed for an agricultural or industrial society cannot appropriately educate our next generation. As a researcher, therefore, I had the intention to gain insight into student learning in biology in senior high school in Taiwan and explore possibilities for its enhancement.

1.2 Background to education in Taiwan

As a context for this research, the background to Taiwanese education is described. This section profiles the education developments before the establishment of the Republic of China (ROC), often referred to as Taiwan, and then provides a more detailed description of Taiwan's current education system, its characteristics and reforms.

Education is highly valued by Chinese people as one of life's most worthwhile pursuits (Watkins & Biggs, 2001; Cheng, 1998). Organised educational activities commenced in mainland China over four thousand years ago. The formal initiation of Chinese education is from the Spring-Autumn Era (770-221 B.C.), although civilians were not allowed to receive education until the feudal system collapsed (at the end of that era) (Hu, 1978). The Confucian tradition (which is elaborated thoroughly in Chapter 2) on which education is based, was predominant in those times and later it extended its influence to all Asian people (Chen & Chung, 1993). The civil service examination, which began in the Tsai Dynasty (589-618 A.D.), achieved its ends of selecting government officials by requiring the repetition and duplication of the classic works of scholars. To this end, intellectuals engaged in years of study and recited passages with little understanding (Hawkins, 1981; McKnight, 1994). This affected intellectuals' attitudes toward learning and misrepresented the purpose of education. To be an officer became the primary concern for most intellectuals. Not until the Ching (Manchu) Dynasty was over-thrown and the ROC was established by Dr. Sun Yat-Sen in 1911 was the civil service examination abolished and a new education system implemented. Even so, for political reasons, the new system had no chance to develop because of the disasters that followed. The provincial warlords controlled their territories to impede the unification of the nation. Then the Japanese invaded China in 1938, and World War II caused serious losses to the country. At the end of World War II, in the autumn of 1945, another programme was launched to rehabilitate the national education system. When the Chinese Communists rapidly expanded, the government of the ROC was relocated to Taiwan in 1949. Throughout this shift, the culture of education continued as it had during the previous five thousand years with very few developments. Since 1949,

when Taiwan was separated from Mainland China, education has undergone significant change. Taiwan's education system and examination process was modified when the government changed (Huang, 1997).

Primary education has been universally available in Taiwan since 1945. As the demand for secondary education grew, nine years of basic education (six years of elementary and three years of junior high school) became compulsory, and free from 1968. Then an expansion of senior secondary education began. Taiwan's education system now follows a basic 6-3-3-4 pattern: six years at elementary school, three years at junior high school, three years at senior high school and four years at university or college. There are now two extremely competitive joint entrance examinations, which are normally held in summer, before student entry into senior high school and before they enter university or college. Successful candidates are assigned to a senior high school or university/college according to their preferences and examination outcomes. College and university graduates may apply to graduate school after passing an entrance examination. The length of study for graduate programmes varies from one to four years for a master's degree and two to seven years for a doctoral degree (Ministry of Education of ROC, 2002b).

The Taiwan education system has two main characteristics; a centralised system and an examination culture. In the centralised system the curriculum is controlled by the central government. Within this centralised curriculum, all teachers are expected to cover the same syllabuses, and reach the curriculum goals established by the government. The second feature is the examination culture. With a strong desire to obtain high scores in senior high school and university entrance examinations, students and their parents face considerable pressure. Students and parents transfer this pressure to the school administrators and teachers, which greatly affects the teaching and student learning (Huang, 1997; Upton, 1989). This aspect will be discussed in Section 2.3.2.

Students commonly emerge from the mainstream system skilled, well-informed and self-disciplined. Literacy is high. Educational opportunities are varied and widely accessible. Nevertheless, the educational system in general has been

criticized for its inflexibility and for failing to address the needs of Taiwan's rapidly changing society. Meanwhile, there is growing dissatisfaction with the emphasis on examinations. As a result, education reform has become an important issue in the development of Taiwan. The Commission on Educational Reform (CER), headed by Nobel laureate Lee Yuan-tseh, was formed in late 1994, and education reform started in 1997. A new Nine-year Comprehensive Curriculum for Elementary and Junior High Education was designed for compulsory education for Years 1 to 9. The curriculum was implemented only for first-grade students in SY (school year) 2001, then second, fourth, and seventh graders in SY2002; and finally to third, fifth, eighth, and sixth and ninth graders in SY2003. Revisions to the policy will be made after reviewing the results of this four-year trial (Ministry of Education ROC, 2002b). Although the new curriculum attempts to set students free from teacher-centred, textbook-driven and examination-oriented education, it has been under serious debate since its inception. The implications of the policy change for the Joint University Entrance Examination will be discussed in Chapter 2.

1.3 The senior high school biology curriculum in Taiwan

Before 1983, the biology curriculum was taught only in Grade 10. This curriculum was based on the inquiry-oriented BSCS (Biological Science Curriculum Study) yellow edition from the United States (Yang, 1977). After 1983, because of the revision of senior-high curriculum standards, a biology curriculum was taught in Grades 10, 11 and 12 (Ministry of Education of ROC, 1985). Curriculum standards for all levels of schools are revised approximately every ten years. The latest revision, in 1995, was made by experts appointed by the Ministry of Education (Ministry of Education of ROC, 1996). These experts included curriculum specialists, teacher educators, school teachers and administrators. The revised biology curriculum was promulgated by Ministry of Education and one set of textbooks was published by the National Institute for Compilation and Translation. From 1999, non-governmental organizations were delegated to edit and publish senior high school textbooks in line with the 1995 revision of senior-high curriculum standards. Senior high school administrators were then given the freedom to select their own textbooks (Zhan, 2004).

According to the current senior high school curriculum standards (which have been implemented since October 1999), students in Grade 10 must take basic biology for two hours weekly for half a school year (a regular week is 33-37 teaching hours). Biology is an elective for Grade 11 and 12 students. They take the course for two and three or four hours weekly respectively (Ministry of Education of ROC, 2002c) (see Table 1.1).

Grade	Subject	Teaching hours per week	Compulsory/Elective
10	Basic Biology	2	Compulsory
11	Life Science	2	Elective
12	Biology	3-4	Elective

Table 1.1: The senior high school biology curriculum framework

The common goals for the senior high school biology curriculum standards and their example areas are:

- (1) to develop the basic literacy in the life sciences that modern citizens should possess to understand humans' living environments and the roles they should play (related to **attitudes**). For example, 'human and biosphere' (in the Grade 10 textbook) provides evidence that humans have overused natural resources, which has led to the ecological environment being destroyed, wild life being almost extinguished and the environment becoming seriously polluted;
- (2) to explore the basic knowledge of the life sciences (related to **cognition**) and establish a view of the modern life sciences so as to be able to solve the problems encountered in daily life (related to **process skills**). For instance, 'human immune system' (in the Grade 12 textbook) teaches that human are infected with diseases via pathogens. Through understanding the life cycles and characteristics of different pathogens, humans may maintain health by avoiding infection; and,
- (3) to cultivate student interest in the life sciences (related to **attitudes**), understanding of the mystery of life (related to **cognition**); appreciation of the achievements and progress of modern biological science and

understanding of the relationship between biological science, and social science (related to **attitudes**). For example, ‘life science and human life’ (in the Grade 11 textbook) encompasses genetic engineering. Humans have successfully transferred genes from one species to another species to enable plants to become anti-insect, animals to grow fast, and bacteria to generate hormones or medicines, and so on. These contributions of biotechnology benefit humankind considerably. However, they also bring ethical, religious, social and legal problems which demand attention.

The key objectives and teaching content outlined in the three grades are listed in Appendix 1.1-1.3. In the objectives of the Grade 10 curriculum, attitudes are accentuated. In contrast, in Grades 11 and 12, cognition is emphasized. The sequence of content begins with ecology, moves to understanding the life processes of the individual, and then explores the fundamental principles of life processes at the cellular and molecular level. In the current curriculum, although the curriculum seems to focus mainly on cognition in biology, process skills and attitudes have more emphasis than in the previous curriculum. The change is due to the globalisation having forced the senior high school education system to face the challenge of the rapid transformation of society and so there is no alternative but to make adjustments (Ministry of Education of ROC, 1996). Additionally, the Nine-year Comprehensive Curriculum for Elementary (2001) and Junior High Education have been implemented (2002). In order to connect the junior with senior high education, the revision of senior high school curriculum has been developing.

1.4 The researcher and the problems of biology education in Taiwan

The researcher graduated from the Biology Department of the National Taiwan Normal University and received a master’s degree in the same department and university. She has taught junior and senior high school biology for more than fifteen years, and is currently teaching in a senior high school in Taiwan.

Taiwan's secondary education is criticized in that 'the entrance examination directs the instruction'; the style and emphasis of instruction is determined by the content and style of the examinations (Huang, 1997). Many Taiwanese parents expect their children to bring honour to them by gaining a good record in their formal schooling (Lin, 1992). This utilitarian view deeply affects their children's learning, teacher teaching, and school policies (Smith, 1991a). Universities are ranked by society. Their entrance policies are tightly associated with examination results, leading to the content of the examinations being of the greatest concern to teachers and students. Marks are regarded as the result of both learning and teaching. Teachers elaborate the content of textbooks according to the sequence in the textbook. Their students concentrate on the lectures and practice repetitively after school, to prepare for examinations. Predetermined outcomes are tested in the examinations. In this way, teaching is equated with an attempt to supply the student with large amounts of knowledge in a short time; and students sit still in their chairs waiting to be instructed (Huang, 1997). However, according to the researcher's observations, some students do not focus their attention on getting work done. Consequently, they spend time apparently learning, but no actual comprehension is generated - the students actually fool themselves and their teacher would not necessarily be aware of this. Experiment classes are often sacrificed because the content of experiments is not normally part of formal assessment procedures, therefore there is no need to invest time in doing experiments. Memorizing the outcomes of experiments is enough to cope with tests. Students, especially Grade 12 students, experience unceasing quizzes and mock examinations, which sometimes replace normal teaching, to help them become familiar with the nature of entrance examinations. Learning, therefore, is not a happy experience for students.

Taiwan is a degree-driven society. A diploma is not only a stepping-stone for beginning one's career but also a valuable asset throughout that career. The only way to obtain a degree is to pass examinations. Examinations are believed the most fair and objective way for society to select personnel (Lin, 2001). While transmission teaching and rote learning might be effective to prepare for examinations, they are of little help to students in developing diverse abilities and promoting learning motivation. The result is teaching becomes boring and student

interests and learning potentials are frequently buried in so-called ‘objective’ and ‘fair’ examinations (Yang, 1994).

On the other hand, in terms of the common goals and individual grade objectives of the senior high school biology curriculum standards, senior high school students are expected to have an interest in life sciences, a basic literacy in the life sciences, and abilities in collecting, analysing and interpreting data. Also, they are supposed to understand the relationship between the life sciences and human life, and to cultivate creative thinking in relation to conducting life science research. These expectations are contrary to what appears to happen in the present senior high school student biology lessons. For example, most biology teaching content is unrelated to the student lives, therefore it is hard to demand that the students understand the relationship between life science and human life. Another instance is that the amount of content and the structure of lectures force students to learn superficially rather than by thinking deeply. Furthermore, laboratory work tends to be of a recipe-type with predetermined outcomes, which does not help students develop their ability to conduct life science research.

Taking all this social and historical background into consideration, the researcher realised that reaching the goals of the senior high school biology curriculum standards in the current biology classroom context was a next to impossible task. Something needed to change, so, with the intention to improve the student learning, the current study was commenced.

1.5 An overview of the thesis

This thesis seeks to document the current situation of student learning and to evaluate the influences of a classroom intervention programme in a senior high school biology class in Taiwan. The thesis depicts the background, theoretical framework and the design of the research, presents the existing teaching and learning situation in senior high biology in Taiwan, and discusses the intervention program including its design, implementation and evaluation.

Chapter 1 introduces the background to education in Taiwan, the Taiwanese senior high school biology curriculum, the researcher's background, the problems in biology education in Taiwan, and an overview of the thesis.

Chapter 2 discusses the background to student learning of biology in Taiwan. It explains the Confucian-heritage culture relevant to education and public beliefs arising from the culture. In addition, the significance of examinations and their effect on teaching and learning, the nature of new policies for entry into university or college, and the development and current situation in biology education in Taiwan are discussed. The relevance of this chapter to the remainder of the thesis is explained at the end.

Chapter 3 provides an overview of research into student learning in senior high school biology to highlight ideas about how student learning might be enhanced. It outlines current conceptualisations for student learning in science/biology and discusses how these relate to this study. The influence of student and teacher beliefs on learning, and pedagogies related to the teaching and learning of biology are also detailed. Finally, the research aims for the study are introduced.

Chapter 4 raises four research questions to guide this study. An interpretive paradigm in line with the qualitative and quantitative methods necessary to examine student learning is employed in this study. This chapter elaborates on the research design and how the data are collected and analysed. The reliability, validity and ethics of the study are also detailed.

Chapter 5 investigates student perceptions of the lecture classes in biology, including their reasons for taking biology, thoughts about learning biology and changes they would like to see in the lecture classes. Also investigated is student approaches to learning biology; preferred, currently used, most helpful and those that might increase student marks. Student perceptions of the experiment classes in biology are examined, including their perceptions of learning and changes they would like to see in the experiment classes. The data presented in this chapter arise from student interviews and questionnaires.

Chapter 6 investigates teacher perceptions of biology teaching, student learning in biology, and their views of interactive teaching and open-ended activities. The data in this chapter are primarily from teacher interviews.

Chapter 7 sets out the intervention that was devised in the light of the outcomes of the first part (Chapters 5 and 6) of the study and describes the implementation of the intervention. The programme is characterised by interactive teaching and open investigations. Assessment for learning was employed during the above two activities. In this chapter, the principles for the intervention, the details of the intervention, the teaching approaches used in the intervention and how the intervention was implemented are elaborated.

Chapter 8 evaluates student learning in the interactive teaching classes and student responses to the teaching. It includes evidence of student learning in the interactive teaching classes, student perceptions of the interactive teaching classes, student responses to the traditional lecture classes and interactive teaching classes, student scientific epistemological views, and a comparison of traditional and intervention student test achievements.

Chapter 9 sets out an evaluation of student learning in the open investigations and student responses to the investigations. It includes evidence of student learning and student perceptions of their learning in the open investigations and student comparisons of closed experiments and open investigations.

Chapter 10 answers the research questions and discusses the significance of the findings. It indicates implications and offers some recommendations for future research. The impact of the study on the researcher and limitations of this research are also presented.

Chapter 2

The background to student learning of biology in Taiwan

2.1 Preamble

Asian people invariably have a high regard for their children's education (Cleverley, 1991; Gow, Balla, Kember, & Hau, 1996; Leestma & Bennett, 1987; Smith, 1981; Tu, 1978). Education is assumed to be crucial not only as a ladder up the social hierarchy, but as training towards the development of a better individual (Ho, 1976; Mordkowitz & Ginsburg, 1987). In the Chinese context, these beliefs about the value of education are embedded in Confucian-heritage cultures and traditions (Cheng, 1998; On, 1996). In the researcher's teaching experiences over many years, she found student thinking about learning, and their reasons for acting, were rooted in Chinese cultures and traditions. Therefore, it is not feasible to discuss Taiwanese student learning without understanding the influence of Confucian heritage culture and traditions on learners, parents, teachers and education policy-makers. Meanwhile, examinations have been strongly related to Chinese education since the civil service examination in the Tsai Dynasty (581-618 A.C.). It is through them education came to be seen as a crucial route for upward social mobility. Although the examination ended in Chin Dynasty (1644-1911 A.C.), it continues to exert a strong influence on parents, students and teachers, and this influence will be discussed in this chapter.

This chapter describes the background to student learning of biology in Taiwan. Confucian-heritage culture and its traditional beliefs are introduced. The implications of Confucian views for parents, children, teachers and students are discussed (Section 2.2). The way examinations orient student learning and the Taiwan's entrance policy at high school level are elaborated in Sections 2.3 and 2.4 respectively. The development of and the current biology education in Taiwan are discussed in Section 2.5. The relevance of this chapter to the remainder of the thesis is explained in Section 2.6.

2.2 Confucian-heritage culture and beliefs

Confucian-heritage culture and traditional beliefs contribute to a unique Chinese culture. They shape interpretation of Taiwanese secondary school student academic learning and are crucial in the interpretation of student responses to any change in the learning context. Confucian-heritage, culture along with the implication of Confucian views for parents, children, teachers and students are elaborated in this section.

2.2.1 Confucian-heritage culture

The main publications representing Confucian heritage thought (all conceived in 500-300 B. C.) are the four books: *Confucian Analects*, *The Doctrine of the Mean*, *The Great Learning* and *The Works of Mencius*. The foundation of Confucian-heritage thought, which is moral education and its implementation, is found in these four books. Space does not allow a thorough study of these books and so the scope of this review is restricted to points relevant to the Confucian conception of education. They are: the ideal of Chinese life, the meaning of institutions and collectivism; the influences on learning; and the significance and limitations of education. Finally, Confucian-heritage culture is summarized.

The ideal of Chinese life, the meaning of institutions and collectivism

In order to understand Chinese education, it is necessary to have an understanding of the ideals of life and thought of the Chinese people (Chiang, 1963). The main ideas pertinent to education are the importance of duty, the meaning of institutions and the role of collectivism.

- **The importance of duty**

From a Chinese perspective, duty is one of the most fundamental ideals of life. One must attain the highest good, *summum bonum*, to fulfil the duties of life. To arrive at the supreme good, one is required to perform to the full one's duties in life. The Chinese believe the fulfilment of duties is the only way to happiness, and happiness is collective rather than individual. Only through the mutual devotion of the members of the Family and the State can peace, order and prosperity be attained. Furthermore the devotion itself is happiness too. No happiness is

permanent unless it is connected with duty (Chiang, 1963). Confucius thought more highly of conducting duties than even of gaining knowledge. He said:

A young man, when at home, should be a good son; when out in the world, a good citizen. He should be circumspect and truthful. He should be in sympathy with all men, but intimate with men of moral character. If he has time and opportunity to spare, after the performance of those duties, he should then employ them in literary pursuits. (Analects, I.6, James, 1948, p140)

According to Chiang (1963), as a consequence, a teacher must do his/her utmost to fulfil his/her duties relating to teaching; a student, to study. This explains why Taiwanese teachers do as they can for students and students work hard to study.

- The meaning of institutions

Institutions are viewed as an expression of life, permeated with the idea of happiness through, and in, duty. The home is seen as the fundamental institution. It is seen as a prototype of the state and the state is based upon families. The father is likened to the sovereign of the state and the other family members to the subjects. It is the responsibility of the father to ensure the welfare of all the family members. In return, the family members show respect to him and recognize his authority. Similar principles apply to the sovereign and his subjects and to schools as an institution of the state. The purpose of school is to teach the people human relations - the mutual devotion of parents and children, of sovereign and ministers, of husband and wife, of young and old (Chiang, 1963). This explains the phenomenon that Chinese students respect their teachers and their teachers provide the students with their knowledge as they can.

- The role of collectivism

Chinese people believe that the future of individuals from the same group is interconnected, and unquestionably the collective effort will bring wellbeing for each person. The individual gains an identity only through group membership and by having a defined position in the social hierarchy. Human relations are organised into a configuration of hierarchy, where individuals are regarded as components of a community. A group/community is supposed to be harmonious and flourishing if each individual conforms to group norms and acts according to the group interest (Cheng, 1998; Leung, 1996; On, 1996). In short, individuals are expected to submit themselves to the collective. Earley's (1989) study supported

this assumption. He found that the idea of collectivism made Chinese people avoid wasting time and encouraged working for the group interest. Education is considered to play an important role in developing in children the norms and expectations of the society (Cheng, 1998).

In sum, Chinese people under Confucian-heritage culture consider that the most fundamental life duty is to attain the supreme good; the members of an institution should devote themselves to each other and they should act based on collectivism.

The influences on learning

Following on from the ideal of Chinese life, the meaning of institutions and collectivism, Chinese people consider effort, environment, memory, thinking and the nature of motivation are important in learning.

- **The role of effort in learning**

In order to attain the supreme good, unceasing effort is encouraged by Confucius. He remarked: 'I am not one born with understanding. I am only one who has given himself to the study of antiquity and is diligent in seeking for understanding in such studies' (*Analects*, VII.19, James, 1948, p. 201).

Confucius stressed his knowledge was not inherited, but obtained by means of diligent study. He advocated that all through one's life, one must devote one's time to securing knowledge through learning. He stated: 'Learn as if you could not reach your goal and always fear also like you should lose it' (*Analects*, VIII.17, James, 1948, p. 213). An old Chinese proverb says 'Diligence is able to make up for dullness' suggesting effort can compensate for a lack of ability. The driving force of effort comes from a sense of duty, so that a student, for instance, should make a major effort to fulfil his/her duty to study. It follows that there are no dull students, but only lazy students who have not exerted sufficient effort to learn well and who, consequently, will not obtain true happiness. The same interpretation can be applied to a teacher, a father, a farmer, a sovereign and so on. A sense of duty is considered to support one to make the effort to do one's best in performance, physically and mentally, during the process of gaining knowledge through learning.

- The importance of environment in learning

The same individual will respond in a different way when encountering different environments. Therefore, the Chinese people pay careful attention to the environment in which the children learn (Stevenson et al., 1992). For example, when Mencius was in his boyhood his mother shifted house three times for him because he had no desirable neighbours. The first time, he had a neighbour whose occupation was constructing tombs. He was affected by that and often pretended to bury dead people with his playmates. The second time, he had a neighbour who was a businessman. Consequently, he often pretended to peddle goods in the streets by chanting. The third time, his mother shifted their house next to a school and he started to study. From that day forward they did not move again (Chinese Research Group, 1984). His wise mother's method of supporting teaching this prodigious child has ever since been regarded by the Chinese as a model. Mencius himself demonstrated the influence of environment using the example of barley. The same kind of barley seed may produce different quantities of crops depending on the differences in the quality of soil and its degree of fertility, the quantity of the rains, and the amount of labour that the farmer devotes to it. In the same way, people learning varies greatly because of differences of the environment. Hence, the student learning environment is important in this study. It includes not only the school context but also teacher and student beliefs related to student learning.

- The place of memory

From a Chinese perspective, memory has a contribution to make in learning; facts can supply the material for thought. For this reason, it is considered important that each learner develop an understanding of the fundamental information in a specified field of knowledge. Memory is not, however, the recall of isolated or undigested facts. When one of Wang Yang-min's (a philosopher of the Sun Dynasty) disciples asked him what could be done, for he could not remember what he had studied, Wang replied:

What you want is to understand and not to memorize (what you have studied)...To understand (what you have studied) is only of secondary importance; what you want is to know the sources (of truth) in yourself through study. If you simply want to remember, you will not be able to understand; and if you simply want to understand (what you have studied), you will not be able to know the sources (of truth) in yourself. (The Works of Wang Yang-min, Dialogues, Section 175, cited in Chiang, 1963)

That is, to regard memory as an end in itself is not the goal. To understand what is in books, irrespective of personal requirements or experience, is of secondary importance. From a Chinese perspective, the most important point is to understand the knowledge of literature and incorporate it into one's own experience (Chiang, 1924).

- The role of thinking

Confucius remarked: 'Study without thinking is labour lost. Thinking without study is perilous' (*Analects*, II.15, James, 1948, p. 150). Put another way, learning without thinking is blind. Although Confucius emphasized the importance of thinking, he recognised that thinking without studying only resulted in thinking in a void. From his point of view, one must learn extensively, examine carefully, think prudently, distinguish clearly and practise sincerely during the learning process (*The Mean*, XX.19, James, 1948). He perceived learning and thinking as two sides of a coin and suggested one should not stop learning unless one has gone through each of the following successfully (On, 1996):

He should not stop learning until he has known all, neither should he stop asking until he has exhausted his questions, nor should he stop thinking until he has found all the answers, nor should he stop distinguishing until he has made the differences clear, nor should he stop acting until he has done his sincere best. (The Mean, XX.20, James, 1948, p.413-414)

Obviously, Confucius considered thinking and learning to be complementary to each other.

- The nature of motivation

One of the main characteristics of Chinese students, compliance, derives from filial piety. Mang-sun, one of Confucius' disciples, asked what filial piety was. Confucius suggested to him not to disobey his parents (*Analects*, II.5, James, 1948). Based on that instruction, Chinese students are inclined to study hard to reach their parents' expectations, because the adults believe that engaging in study leads to success. Chinese students are inculcated with the idea that 'learning is for the sake of yourself – to reach the superior good' from childhood. However, the definition of 'learning is for the sake of yourself' has been misinterpreted ever since the advent of the civil service examinations in the Tsai Dynasty. The civil examination was regarded as a social ladder that enabled upward mobility (Cheng,

1998). An old Chinese idiom said: ‘Although you study anonymously for ten years, once you are successful, you will become well-known in the world’. The implication of the idiom was that the only track for people to rise from obscurity to attain fame, wealth and high social status was taking the civil examination successfully. Undeniably, it attracted great attention from persons who were from humble backgrounds, and encouraged them to make the utmost effort to be winners in the competitive examinations. The belief in the possibility of upward social mobility through educational success became a crucial driving force for the persons of obscure origin as a way to strive for a bright future (On, 1996). A significant level of education is still seen as the primary, though no longer the only, route to success (Cheng, 1998).

Chinese people strive for achievement on one hand to develop their personal reputations, and on the other hand seek to glorify their ancestors and families (Cheng, 1998; Yang, 1994). Failure means losing family face, which is highly valued in Chinese society. Face refers to the status expectations an individual is supposed to have, based on his/her group-associated identity (Cheng, 1998). According to Ho (1976), ‘losing face’ means to ‘fail to meet essential requirements placed upon him by virtue of the social position he occupies’ (p.867). The individual’s status within the collective leads unsurprisingly to an education system that accentuates examinations and competition. However, the emphasis on effort and hard work in education in Chinese societies is partly derived from the collective culture (Cheng, 1998). High scores on a test are regarded as a representation of diligence and gain approval from society members. If the students fail to attain their highest aspirations, they feel that others are contemptuous or disapproving of them (Watkins & Biggs, 2001). The prevailing emotions of anxiety, embarrassment, guilt and humiliation occupy them when they get low marks and they are afraid of failing (Grant & Dweck, 2001). Stevenson and Stigler (1992) observed that:

Group identification provides a strong, effective means of heightening children’s motivation toward particular goals... This does not mean that individual accomplishment is disparaged; rather, it becomes something that enhances the prestige of the child’s group or family... The power of the group is also used as a means of motivating children. (p.89-90)

An individual's achievement enables him/her and his/her family to gain face. On the other hand, an individual has to pay a high cost - losing his/her family face for failure (Salili, 1996). For a number of Chinese people, face even weighs more than their properties and lives. Therefore, it is not surprising to see children labour under inconceivable pressure to be successful academically. It is incredibly prevalent in Chinese society that parents place the heavy pressure for success in examinations on their children's shoulders, being afraid of losing face in front of their relatives or close friends (Cheng, 1998). However, this does not mean that learning is for the sake of oneself is inauthentic in Chinese culture. A number of students are keen to learn and find academic activities meaningful and worthwhile. Nevertheless, academic learning in Taiwan is dominated by competition in the current examination system driven by parent and teacher expectations.

The significance and limitations of education

Education is the method of life and thought, while, at the same time life and thought are the content of education (Chiang, 1963). The significance of education was stressed by Mencius. He believed that even though the nature of man is good, yet, if education is ignored, men are not far different from beasts (*Mencius*, IIIA.8, James, 1948). According to Confucius, personal improvement is the underpinning of all education (*Analects*, XIV.25, James, 1948). However, education is important for societal development as well as for personal improvement (*Analects*, XIX.13, James, 1948).

Confucius recognized the existence of differences in individual endowment and that differences in individual capacities set the limits of education, although fundamentally he considered that everyone is educable. However, he concluded that once one possesses knowledge, it does not matter whether one is born with knowledge or attains knowledge by experiencing torment to learn, it is all the same. In other words, the individual differences in intelligence do not inhibit one's educability, but the attitude to learning does (On, 1996). In the light of the idea that students have individual difference, Confucius suggested teachers should respond differently based on their capacities (Overseas Chinese Affairs Commission, 1982).

Summary of Confucian-heritage culture

To summarize Confucian-heritage culture, Chinese people are taught: to attain the supreme good to fulfil the most fundamental life duty; to devote themselves to each other in an institution; and to act based on collectivism. To develop one's potential to the fullest extent effort is encouraged in learning. During the learning process, learners are thought to be influenced by their environment. This suggests the importance of creating a environment for better learning in the classroom. Memory and thinking are seen to contribute to learning. Chinese students are compliant to their parents, which inclines them to study hard to reach their parents' expectations. They study hard not only for personal improvement but also to glorify their family consistent with ideas of collectivism. In Chinese culture, education is highly valued. Everyone is seen to be educable except those with little desire towards learning; hence learning motivation is seen as indispensable in student learning.

2.2.2 Implications of Confucian beliefs for parents, children, teachers and students

This section elaborates the implications of Chinese culture for parents, children, teachers and students. Affected by the culture (striving for achievement and collectivism mainly), Chinese parents have high expectations and place high demands on their children (Broaded, 1997). They believe that entrance to the highest grade school is an indicator of a potentially more successful future (Yang & Fraser, 1998), which includes a good job, fortune, higher social status (Sue & Okazaki, 1990). They consider hard work will make a significant difference to children's later opportunities (Broaded, 1997). Children are expected to study hard for their own future and family glory. Affected by the belief of institution, a mutual devotion is developed between parent and children (see Section 2.2.1). Parents provide children with the best environment possible (e.g. providing them finance and transportation and doing all household chores). They imply that they are willing to sacrifice and do everything possible to assist them in education (Peng, 1993). They perceive that their sacrifice is worthwhile if their child achieves at higher level than their classmates in school (Salili, Chiu, & Lai, 2001). On the other hand, children attempt attain the best performances they can in school. Consistent with the learning motivation mentioned in Section 2.1.2,

because their parents value education highly, children treat academic study as their first priority. They might take their teacher instructions as truths and do their best to learn in school, irrespective of how uninteresting the learning content is, to fulfil their duties towards their parents (Siu, 1992). A reciprocal relationship between parents' love and children's hard work in school is developed implicitly. Children's striving for achievement is driven by recognition of their parents' sacrifices (Gow et al., 1996).

Teacher roles and their teaching and student roles and their learning are influenced by the traditional culture and beliefs. Teachers hold a highly-valued social position and are usually regarded as knowledgeable experts that no student should question (Huang, Aldridge, & Fraser, 1998; Wang, Tuan, & Chang, 1998). However, student failure is often attributed to the inattention of their teacher (Smith, 1991b). Chinese also assume that the major responsibility of a teacher is to help students succeed in entrance exams (Hsiung & Tuan, 1998). Consequently, teachers perceive huge pressures from parents and consider they should provide students with lots of knowledge (Huang, 1997; Huang et al., 1998). Therefore, they tend to employ didactic rather than interactive teaching to help students achieve good academic performance (Yang, 1994). Affected by the belief of effort, they perceive repetitive practice can enhance student academic progresses (Yang & Fraser, 1998). Despite this, Lunetta and Lederman (1998) argue that drill and practise oriented work sheets merely develop lower level knowledge. In science, teachers assume that student mastering recondite concepts is a prerequisite for successful learning. On the other hand, students are supposed to concentrate and listen to teacher lectures and to study hard after school. Following teacher instruction is an obligation. Raising questions in class can be confused with an interruption to teaching and/or a challenge to teacher authority (Huang et al.; Wang et al.). Students tend to restrict their learning to what is specifically set out in the curriculum to increase the chance of examination success (Gow et al., 1996).

Supportive parents, compliant children, devoted teachers, and hard-working students are seen to contribute to academic success (Stevenson, Lee, Chen, Kato, & Londo, 1994). These covert beliefs and subsequent patterns of behaviour

inherent to Taiwan societal culture have an immense effect on student academic learning.

2.3 Examination-oriented learning

Chinese's examination system arose from the civil service examination which was introduced as a means of selecting government officials within the Imperial Civil Service in 124 B.C. (Hawkins, 1981). In current Taiwanese society, student efforts and potential are best affirmed by successful achievement in examinations. For this reason, examinations orient student learning. This section elaborates on the examination system and the impacts of examinations on education in Taiwan.

2.3.1 The Taiwan examination system

Examinations are currently enshrined in the Taiwan constitution. The Executive Yuan, one of five national governmental branches, controls the national examinations and the civil service system. Working in the civil service is regarded as a guarantee of employment for life; and so the examinations for entry to government jobs are extremely competitive. Once government certification is obtained, subsequent promotion in many careers is still based on examination results.

Although the civil examination has gone forever, its spirit remains firmly embedded in the modern education system. Throughout their schooling, students take rigorous examinations (Lunetta & Lederman, 1998). Students who enter a new school during their secondary or tertiary education have to take entrance examinations for admission. Because students seek to enter the best possible schools, the entrance examinations are extremely competitive (Broaded, 1997). In addition, three term examinations and more than one hundred ordinary tests are typically undertaken by secondary school students in a semester (six month period). For 9 and 12 graders, the frequency of testing can reach more than three times per day, and sometimes students take seven tests in a day. Thus, a high frequency of tests is very common in current secondary schools (Lin & Hsu, 2003; Yang, 1994).

2.3.2 The impacts of examinations on education

In this section, the impacts of examinations on teaching and learning are categorized into examinations guide teaching and learning, promote student attendance at cram schools, and affect student beliefs about science.

Examinations guide teaching and learning

Teaching in Taiwan secondary schools is very closely tied to the national standardized curriculum. Teaching which assists students to gain top marks in the joint entrance examination (all the secondary students sit the same entrance examination in Taiwan), normally teacher-centred, is perceived as efficient teaching (Huang et al., 1998). Teachers usually impart only the information which will appear in entrance examinations (Yang, 1994). Student-centred teaching is often criticized on the grounds of teacher lack of diligence and students learning less than with teacher-centred teaching (Huang et al.). In order to increase student success rate, teachers utilize supplementary exercises, and instruct students how to compose the correct answer to test items rather than encouraging thinking (Yang & Fraser, 1998). Overall, this leads to the teaching in secondary schools being conservative and rigid.

Students are encouraged to use memorizing as learning strategy because Taiwanese teachers frequently make use of commercial sets of questions, quizzes and term examinations to monitor student academic growth (Tuan, Chang, Wang, & Treagust, 1998). This is justified on the grounds that, if only factual information is required to gain a high score, then memorization of facts may be the most efficient strategy to employ (Salili et al., 2001). Taiwanese students respond by repetitively practising supplementary exercises to cope with tests. Thus, the nature of school assessment directs student learning strategies and has a profound influence on student cognition and their involvement in learning tasks (Boekaerts, 1987; Volet, 1997). It is entirely possible that these are not student real attitudes toward learning. Tang and Sui (1991) suggested that some students attempt to adopt a deep learning approach, but soon discover that course assessment requires them to reproduce defined bodies of knowledge. That is, they commence by trying to comprehend material, and then shift to learn it by heart to pass the examinations. In order to save time, students allocate their time to

subjects in proportion to the ‘importance’ of the subjects. Students restrict their study to what the teacher teaches. They think it is unnecessary to exhibit any additional learning (Gow et al., 1996). A similar view was raised by Garner (1990), who persuasively argued that there is no need to persevere with more time consuming study patterns if primitive routines get the work done. It becomes clear that current assessment practice often misinterprets memorising as learning, and restricts the scope of what is learned.

Examinations promote student attendance at cram schools

In attempting to pass examinations, the majority of the students attend cram schools (Guan, 2001; Huang et al., 1998). As of the end of November 2002, there were 10,071 cram schools licensed by the Taiwan government. The majority, 7589, provide academic assistance in mathematics, physics, chemistry and English, or prepare students for the exams required for study abroad (Ministry of Education of ROC, 2003).

Normally, students go straight to cram school after their dismissal from formal school and then arrive home between 9 and 10 pm. They are often tired and this increases the pressure on them, mentally and physically (Yang, 1994). Junior and senior high graduates who fail the entrance examinations or are not admitted to their choice of schools often choose to study for another year in cram schools.

Examinations affect student beliefs about mathematics and science

In the IAPE (International Assessment for Educational Progress) outcomes workshop in Taiwan in 1993, participants, including principals and teachers from primary and secondary schools, administrators of education and educational researchers, reached the consensus that, affected by the examination culture, student attitudes toward science have the characteristics as follows:

- (1) they memorize principles, formulae and laws without understanding and are unable to integrate teaching content by thinking to construct their own understanding;
- (2) in their understanding of learning processes and the application of scientific methods, students merely seek the skills to answer the questions on test sheets rather than logical reasoning and integrated knowledge; and,

- (3) in regard to their attitude towards learning, students desire to obtain high marks instead of real learning; likewise, in relation to the thinking process, they stress memory recall to obtain information quickly without deep thinking.

These beliefs impede the development of higher order thinking skills, including ability of integration and creativity and problem-solving ability (Yang, 1994).

2.4 The University entrance policy

Whether secondary students have subsequent learning opportunities in senior high school or university depends on student ability to pass entrance examinations. Hence, there is a need to understand these entrance policies, and some of their critiques, to understand their relationship with student learning.

The University Joint Entrance Examination Programme (UJEE) was first implemented in 1954. The Joint Board, College Recruitment Commission, which is mostly constituted of university principals, is responsible for UJEE. The Commission is controlled by the 'Entrance Examination Centre' which is the sole organization to oversee research concerned with improving the university entrance system and examination measures (Ministry of Education of ROC, 2002a).

The influence of the Joint Entrance Examination has been gradually diminishing as other options have been adopted, such as the Recommendation Screening Examination Programme (introduced in the 1994 academic year). This programme allows students to decide their own majors and choose universities suitable for their own aptitudes and talents, while the universities can still sift out students according to their examination performance. The Entrance by Application Programme was implemented in the 1997 academic year. Any high school graduate who meets an individual university's admission standards can apply for admission (Ministry of Education of ROC, 2002a).

Although criticized as 'the sole examination that determines one's life once and for all', and allowing 'teaching led by examinations', the university entrance examination has greatly influenced the entire Taiwanese society (Kuo, 1993). It has undergone a number of modifications and was completely abolished and

replaced by the Multi-route Promotion Programme for College-bound Seniors (MPPCS) in 2002. This new system comprises student application to a university, selection by recommendation (the same as the Entrance by Application Programme), and a new version of the UJEE. A student who desires to be admitted to university or college by application or selection by recommendation is required to first pass the general Scholastic Attainment Test (SAT) for College-Bound Seniors (Ministry of Education of ROC, 2002b). In the selection by application or recommendation route, the students need to prepare autobiographies, school reports, community service reports and study plans. In the application route, most universities or colleges accept students solely in terms of their performances in senior high school and SAT scores; although some hold further written or oral examinations. For the students who apply or are selected by recommendation for university entrance, the cut-off point falls in May. If the students fail in these routes, they need to sit another examination, which is in reality a new version of the UJEE, in July.

The students who intend to sit the MPPCS are grouped into four categories. All students complete an subject of examination for Chinese, English, and mathematics; the first group of students following the social sciences and humanities track also take history and geography examinations; the second group of students in the physical sciences track take physics and chemistry examinations; the third group of students in medicine or biological sciences take biology, physics and chemistry examinations; the fourth group of students interested in agriculture take chemistry and biology examinations (Joint Board, College Recruitment Commission, 2003). Some students even take the entire battery of tests in order to obtain more entry options. This causes an abnormality in that some second group students are not interested in biology, but take it to increase entry options. The summary of classification of groups, the subjects each group should take and which schools they can enter in university for each group are listed in Table 2.1.

Group Subject	I	II	III	IV
	Social sciences	Physical sciences	Medicine and Bio Sciences	Agriculture
Chinese	✓	✓	✓	✓
English	✓	✓	✓	✓
Mathematics	✓	✓	✓	✓
History	✓			
Geography	✓			
Physics		✓	✓	✓
Chemistry		✓	✓	✓
Biology			✓	✓
Schools they can enter in university	Education, Law, Art , Social Science, Management	Engineering, Information Technology, Natural Science	Medicine, Life Science, Psychology	Agriculture, Physical education

Table 2.1: Summary of classification of groups, the subjects each group should take and the schools they are allowed to enter in university for each group

Although entrance examination policies are criticized, examinations are still highly praised for their fairness. Under this system, children's chances of entering university have nothing to do with their family social status and wealth. Every individual has the same opportunity. The main issue with the entrance examination is that, because the questions in the examination remain virtually the same year after year, classes have a tendency to be conducted in an unchanging style with learning largely a matter of the memorization of facts (Kuo, 1993). The new test SAT for senior gradulators, emphasizes the main concepts, relevance to daily life, problem-solving and creativity, and is expected to improve teaching and learning in the future (College Entrance Examination Centre, 2005).

2.5 The development and current situation in biology education in Taiwan

Prior to 1949, when the R.O.C relocated its government to Taiwan, biology education was not a priority. There were more important problems the

government needed to solve, such as poor literacy (Yang, 2002). From 1948 to 1970, there was progress in biology education and the main learning point of senior high school biology was the understanding of phenomena, principles and organism structures. In addition to learning knowledge, students were required to apply scientific methods including observing and conducting experiments, and to understand the relationship between organisms and life. In the 1970s, senior high school biology stressed the need to inspire students to apply scientific methods, and emphasized the significance of genetics, evolution and environment. Students needed to understand previous achievements in biology, appreciate nature from a historical standpoint and to experience the process of the development of science (Yang, 1982). From 1983, the senior high school biology curriculum has emphasised that students need to understand how biology is applied in agriculture and medical science. Additionally, it has emphasized the cultivation of student active attitudes toward science and the development of their ability in problem-solving, appreciating the relationship of modern science development and the humanities, and understanding their responsibility to seek a balance between their needs and that of the earth (Yeh, Wu, & Lee, 1997).

Despite this emphasis, most biology teachers focus on examinations and neglect the wider aims of biology education (Huang et al., 1998). Under the present university and college entry policies, the goal of cultivating the student scientific skills, attitudes and literacy is not satisfactorily reached (Yeh, Wu, & Lee, 1997).

Alongside this there has been very limited research into biology education in senior high schools in Taiwan. What research there has been is mostly linked to the primary or junior high level. Exceptions are action research by Chen and Huang (1999) who attempted to employ constructivist teaching and found group discussion improved student learning environment and attitudes; and by Tsai and Huang (1997) that a teacher's epistemological belief and teaching practice significantly affect student learning. However, they worked with tenth grade students. There is little biology research with eleventh and twelfth grade students in Taiwan, particularly the open work in regular biology laboratories.

2.6 The relevance of this chapter to the remainder of the thesis

Confucian-heritage culture is different from Western culture and this has impacts on education in Taiwan. In the West, the purpose of education is to develop an individual's full potential. In the Confucian-heritage culture it is to cultivate a person to contribute to the society (Cheng, 1998). Without an understanding of Confucian-heritage culture, which is deeply planted in all Taiwanese minds, it is hard to interpret data collected from the teachers and students, especially for Western readers. An example of what is taken for granted by most Taiwanese, but might be supposed odd for Western people, is that most Taiwanese students force themselves to study hard in science subjects or mathematics ignoring their own interests simply because their parents value these subjects (Yang & Fraser, 1998). Also, the extent of the influence of examinations on teaching and learning are beyond Western people's imagination. On the other hand, there are some thoughts about education in the Confucian-heritage culture that are similar to Western educational propositions. Three examples illustrate this. Firstly, Mencius emphasized the significance of the learning environment - people learn from their surroundings. The example included in Section 2.2.1 highlighted the importance of the people in an individual's learning environment. Vygotsky also considered how and what people learn is influenced by other people (Hodson & Hodson, 1998). Thus, Mencius's emphasis on the social influence on learning is consistent with Vygotsky's idea that learning involves social factors. Secondly, the philosopher Wang Yang-min stressed the importance of prior knowledge and that learning involved incorporating knowledge into one's own experience. This view is similar to the model of conceptual change raised by Posner, Strike, Hewson, and Gertzog (1982) where students are considered to develop new conceptions by assimilating or accommodating them into their old conceptions. Thirdly, Confucius perceived the influence of thinking in learning; Western education also stresses thinking in the learning process. These similarities in Eastern and Western thought encouraged the researcher to employ these propositions in designing and conducting the intervention that is the basis of this thesis. The dissimilarities reminded her to be aware that participants' responses might be different from those in international research reports because of their culture. They indicated the need to formulate an intervention for Taiwanese students in biology learning that

drew on both international research and an understanding of Confucian-heritage culture.

2.7 Summary of student learning background in Taiwan

This chapter has discussed Confucian-heritage culture to facilitate the reader's understanding of how it is related to education and explain how this chapter is relevant to the remaining chapters of the thesis. Chinese people are taught they need to fulfil their duty in life, devote themselves to each other in an institution and act based on group interest. These ideas have a great impact on Taiwanese teacher teaching and student learning, particularly student learning attitudes and motivation. Examination is a part of Chinese culture, also has specific influences on teachers and students, including current entrance policies for students who desire to attend universities or colleges. In addition, there is limited research into biology education at secondary level in Taiwan, particularly the open work in regular biology laboratories.

Chapter 3 will describe research on teaching and learning in senior high school biology which, in conjunction with Chapter 2, acts as the framework of this research.

Chapter 3

Teaching and learning in senior high school biology

3.1 Introduction

This study explores student learning in senior high school biology in Taiwan. A picture of student Chinese cultural background in learning was given in Chapter 2. This chapter discusses views of learning and how it related to this study (Section 3.2), the influence of student and teacher beliefs on learning (Section 3.3), and pedagogies related to the teaching and learning of biology (Section 3.4). Collectively, these sections provide an overview of research into student learning in senior high school biology that includes ideas about how student learning might be enhanced. Finally, Section 3.5 introduces the research aims for this study.

3.2 Views of learning

This section documents two views of learning that inform teaching and learning in senior biology and discusses how these views of learning are related to this study.

3.2.1 Views of learning

In science education, two broad perspectives towards learning are evident and have been influential: the behaviourist and constructivist views of learning. These two views of learning are based on different ontological assumptions and incorporate different epistemological beliefs. Each is discussed in turn here as they are relevant to this research which was undertaken in Taiwan and aimed at facilitating student learning.

Behaviourist views of learning

Behaviourist views of learning are based on objectivist epistemological views of knowledge that assume that there exists a knowable reality outside of human subjectivity; so that even though there may be no humans to perceive it; it is still there (Nola, 1997). From this point of view, knowledge involves a universal logical structure of inference, allows that absolute truth to be tested and ascertained (Davis, McCarty, Shaw, & Tabbaa, 1993; Johnson, 1987). Science

therefore has discovered items, such as bacteria, and is doing all that is possible to accurately describe reality. Objectivists endeavour to detach human subjectivity from the facts of reality and to remove values and historical, cultural and social considerations. Consequently, it is believed that knowledge can be transmitted from experts (teachers) to novices (students) because expert's knowledge is much closer to reality than novice's knowledge (Davis et al.). The teacher's role becomes one of simply presenting the factual content of scientific knowledge; the student role is to passively receive this knowledge (Tsai, 2003). It is assumed that students come into classrooms in a *tabula rasa* state, so student pre-instructional knowledge is of no interest. The assumption is that conceptual changes can happen without difficulty (Gilbert, Osborne, & Fensham, 1982). Student creativity and imagination in learning are not acknowledged or appreciated (Aguirre, Haggerty, & Linder, 1990). To sum up, behaviourist views of learning emphasise the role of the teacher and the transmission of knowledge from the teacher to the student.

Behaviourist views of learning have tended to dominate teaching. They have also been predominate in the design of the textbooks and standard tests with these materials their in turn often serving to control what teachers do in schools (Wooley, Woolley, & Hosey, 1999). Research in Taiwan has indicated this phenomenon occurs in senior high school biology curriculum classes and has led to students learning mainly conclusive biology knowledge statements with the main purpose of laboratory work being to verify the knowledge in biology textbooks. This is far from the expected in the current Taiwan biology curriculum goals (Yeh et al., 1997).

Constructivist views of learning

In contrast with the behaviourist view of learning as absorbing knowledge, the constructivist perspective is based on the premise that learners construct meaning actively (Driver & Bell, 1986; Roth, 1990), and then integrate the meaning into their conceptual framework (Millar & Driver, 1987). Seen this way, student existing ideas are important and need to be considered (Magoon, 1977). Constructivism has been increasingly accepted by science educators and this has had profound impact on their thinking (Fensham, Gunstone, & White, 1994;

Driver & Oldham, 1986). Indeed, it is a primary principle of contemporary science education that in the learning of scientific concepts students should develop the ability to construct their own meaning to make sense of experience (Hogan, 1999; Magoon, 1977). Learning is considered to involve both a personal construction of meaning and a social negotiation of meaning (Cobb, 1990; Roth & Bowen, 1993). These two main strands of constructivism are illustrated as follows:

Personal constructivism stresses individual internal knowledge construction processes. Learner construction of meaning from learning material is considered to be affected by personal/individual conceptions, purposes and motivations (Driver & Bell, 1986). Personal constructivism has its origins in Piaget's genetic epistemology and related cognitive science views. Piaget's stage model of cognitive development aims to understand how children develop mental capabilities to access a reasonable level of engagement with the physical universe (Feldman, 1980). In his stage theory, Piaget proposed that children begin by developing concrete operations to act on their world, and then, in the subsequent stage of formal operation, gain capabilities to do with abstract logical-mathematical reasoning. Piaget emphasized the process of knowledge growth as being related to biological factors and preferred to use logical-mathematical reasoning to describe the structure of cognition, which attracted the attention of many mathematics and science educators. When new information comes to a learner and creates cognitive dissonance or conflict, the learner makes an intellectual adaptation through the interplay of assimilation and accommodation, in which the conflict is reduced and equilibrium is established to accelerate cognitive growth (Erickson, 2000; O'Loughlin, 1992). However, Piaget's description of intellectual advancement was based on 'increasing decentralization from subjectivity and toward objectivity' (O'Loughlin, 1992, p.795) and the assumption that logical thinking operations were independent from context (Duit & Treagust, 1998). In short, the common assumption of personal constructivism is that learners personally construct knowledge of the realities of the external world based on their existing experience and this construction of knowledge about reality is tentative. During the learning process, the learner takes the major responsibility for his/her learning. Hence, personal constructivism portrays science learning as primarily based on changes in the mental structure of

individuals. Personal constructivism has been challenged as emphasizing the isolated universals of cognitive development to the neglect of social and cultural aspects in knowledge-construction process (Duit & Treagust, 1998).

Social constructivism, originating from Vygotskian psychology, is concerned with the contributions of social interaction to the construction of knowledge and self (Hodson & Hodson, 1998). Differing from the Piagetian perspective, Vygotsky argued that children develop their knowledge through interactions with peers and knowledgeable adults and communicative tools and skills of their culture. Also, the knowledge construction depends on the learning context the children are in. The main points of Vygotsky's views of learning relevant to this study are discussed below.

Vygotsky viewed social interactions as part of a process leading to the social construction of knowledge (Howe, 1996). Such construction of meaning can occur when students negotiate their comprehension through class discussion and by exchanging opinions (Prawat, 1989). Social constructivist views of learning undeniably bring to light the importance of social-cognitive interaction in the science teaching-learning context.

Interactions between the learner and his/her social environment are essential to the learner's learning (Hodson & Hodson, 1998). Research indicates students need to apply complex cognitive and interactive skills to collaboratively construct knowledge (Hogan, 1999). Teachers can scaffold students to advance their learning. Peer interaction can also serve this purpose. Meanwhile, peer interaction can 'enhance the development of logical reasoning, through a process of active cognitive reorganization that results from cognitive conflict' (Forman & Cazden, 1985, p. 330). The significance of peer communication is easily revealed from children's conversations. They use their own language to express their understanding of what they see as they exchange their opinions with peers and their teacher. In the absence of interaction with others, a child is unable to reach their full potential development. Vygotsky argued a learner's learning is able to advance with tutor or competent peer assistance (Hodson & Hodson, 1998).

This is not to downplay the individual construction of meaning, but rather to advocate that an adult and a child each have their own particular roles and responsibilities towards each other. For teachers, their role is to provide opportunity to motivate their students to engage in a meaningful way with what they would like their students to learn (Reiss & Tunnicliffe, 1999). It is not their role to simply transmit their knowledge of subject matter to their students (Osborne & Freyberg, 1985). For students, their role is to take control over what they learn. In that way, they are more likely to develop and exercise autonomy (Reiss & Tunnicliffe, 1999). In other words, the Vygotskian perspective suggests that the most effective learning is inquiry-oriented, personalized and cooperative. With regard to learning science, this is conducted in accordance with the norms and values of the community of scientists by an experienced guide (Hodson & Hodson, 1998). The teacher's role as a helper and guide will be emphasized in this study. For example, when students have constructed alternative conceptions (understandings which are different from those accepted in the scientific community), the teacher will offer learning activities and interact with them to help them reconstruct more appropriate meanings.

According to Vygotsky's theory, language is an essential tool for interaction during the learning process, one that learners use to mediate thought. He stated that:

The relationship between thought and word is a living process; thought is born through words. A word devoid of thought is a dead thing and a thought unembodied in words remains a shadow. ' (Vygotsky cited in Howe, 1996, p41)

Any attempt to convert partly formed thoughts into fluent speech or into coherent written language propels the development of those thoughts. Therefore, language is not merely an instrument of teaching, but rather a means of learning and a tool of thinking. Especially at secondary school level, the activities of talking, listening, reading and writing can be employed to achieve meaningful student learning (Hodson & Hodson, 1998). In the intervention, student thinking is expected to be facilitated through the learning approaches that students discuss with their teacher and their classmates and/or debate their own views, listen to conversations inside and outside the classroom, read biology-relevant information and write reports or homework.

Vygotsky also proposed that scientific concepts and everyday concepts are not taken in all at once in completed form but both develop over time. People need to move back and forth between the two until they come together in a system. To support this process, scientific concepts need to be applied to real-life situations and real experiences need to be incorporated into a scientific conceptual framework (Howe, 1996). Hence, teaching needs to start with student everyday concepts (Duit & Treagust, 1995) and then move on to include an appropriate opportunity for application, because without an appropriate opportunity for application a concept remains abstract and is not fully understood (Howe, 1996). Therefore, in conducting an intervention, relevance to daily life is a crucial element and needs to be incorporated.

Vygotsky's views of social influence in children learning are similar to those stated by Mencius, both acknowledge the influence of environments (see Section 2.2.1). Vygotsky suggests that adult or more expert help enables a child to learn more successfully and Mencius emphasizes that children learn from people around them and so parents need to choose their children's learning environment very carefully. Since socio-cultural and contextual factors are greatly emphasized, student perceptions of teaching and learning in biology, their interactions with teacher and peers, and their learning preferences will be the focuses in this study as a means for understanding and enhancing student learning.

3.2.2 View of learning related to this study

A social constructivist view of learning underpins this study. A social constructivist view of learning emphasizes the construction of knowledge in the social contexts of the classroom. In biology teaching and learning, interactions with the material world and construction of knowledge about it are, as in all sciences, fundamental. A social constructivist view also acknowledges students need to be encouraged to take responsibility for their own learning but that it is through classroom dialogue that students are provided opportunities for deeper understanding and active cognitive reorganization. Student learning of biology not only involves incorporating new concepts into their conceptual framework but also interacting within the social and physical context. Any such student interaction with their social context and physical world is dynamic, and may

include teacher-student interactions, student-student interactions and/or interactions with tools in the immediate surroundings. The tools involved can be the reading of material or the experiments the teacher provides. Through these interactions, students begin to use the appropriate scientific language and are socialized into the biological science community.

A social constructivist view of learning acknowledges that students actively construct new knowledge based on their prior conceptual framework. For instance, what they observe in experiments depends on their own pre-existing biology concepts. Hence, student prior biology ideas, because they might be different from biologists', need to be identified as a basis for biology teaching. To make biology concepts more meaningful a teacher can encourage students integrate what they have learned into their daily life. The link between their real experiences and biologists' concepts can help students to develop a more concrete understanding of biology concepts. In addition, students coming to know biology is recognised as being based on how they view of learning as this informs the learning strategies they adopt in the classroom. Seen this way, it is important to understand and take into account not only students biology ideas but also their view of learning.

3.3 The influence of student and teacher beliefs on learning

Hogan (2000, p.56) provides a definition of belief: 'When a cognitive structure contains strong affective associations, is linked to one's own identity, has an evaluative dimension, and has direct ties to action agendas it is best described as belief.' In other words, beliefs can encompass student assumptions about the nature of science and learning, along with their goals, purposes, values, expectations and so on. Student epistemological beliefs together along with their motivational beliefs about biology learning have been identified as influential in previous research (Hanrahan, 1998; Lin & McKeachie, 1999; Windschitl, 1997). The influences of epistemological and motivational beliefs on learning are discussed in this section.

3.3.1 The influence of epistemological beliefs on learning

Epistemology is the branch of philosophy related to theories of knowledge and knowing (Bliss, 1995) and epistemological beliefs refer to individuals'

conceptions ‘about the nature of knowledge and the nature or process of knowing’ (Hofer & Pintrich, 1997, p.117). A great deal of research provides evidence that links student epistemological beliefs and student learning. For instance students who believe in innate intelligence have been found to be more likely to display ‘helpless’ behaviour in encountering a difficult task (Dweck & Legget, 1988). Students who believe in quick learning were more likely to oversimplify information and be overconfident in their understanding of information. When asked, students who believed knowledge was simple, certain and handed down by authority tended to recall facts to prove their comprehension of a textbook chapter. In contrast, students who believed knowledge was complex and tentative tended to apply facts to new situations (Ryan, 1984).

In terms of beliefs about science, research indicates that many students have objectivist views on the epistemology of science (Gallagher, 1991; King, 1991). This leads them to favour didactic teaching (Nola, 1997) consistent with the view that learning is gaining information (Gustafson & Rowell, 1995). This view is also associated with a belief that laboratory use will produce accurate results to verify theories (Tsai, 2003). Unavoidably, this has a great impact on student learning. Tsai (1998), working with Taiwanese eighth graders investigating the correlation between scientific epistemological beliefs, found that students with an objectivist view of science were more likely to use rote-like strategies to enhance their understanding, to stress the clarification of teacher lectures, to rely on the teacher, to complain that science was not related to real life, to focus on learning outcomes, and to be motivated by the pressures relevant to course grades and test scores. Students with more constructivist views of science were more likely to use more meaningful strategies, to emphasize opportunities to discuss with others, to control their own learning activities, to be motivated by their own interests, to desire to know more, to focus on learning procedures, and to prefer discovery or more autonomous instructional activities and practical work. In sum, research evidence indicates that student epistemological beliefs are likely to influence student learning approaches, motivation and attitudes and academic performance (Schommer, 1990; Schommer, Crouse, & Rhodes, 1992) and to be highly relevant to their conceptual change achievements (Pintrich, Marx, & Boyle, 1993; Qian & Alvermann, 2000; Strike & Posner, 1992).

Teacher views of science also influence their teaching practice (Roth & Roychoudhury, 1994). Teacher epistemological beliefs seem to play a significant, but not necessarily articulated role, in the classroom and in student learning (Hofer, 1999). For instance, if a teacher emphasizes drill and practice then children are more likely to consider knowledge is a 'mere basket of facts'. In this way, teacher beliefs play an essential role in mediating the quality of student learning and cannot be ignored (Maor & Taylor, 1995; Lederman, 1992).

Identifying student epistemological positions is crucial to understanding their responses to the teaching and learning process (Lyons, 1990) and this is a focus of this study where the intention is to enhance student learning in biology.

3.3.2 The influence of motivational beliefs on learning

According to Karlsson (1996, p.11), motivation is 'the development of conditions promoting intention to act, or learn'. Researchers contend that motivational beliefs influence student preferences for school work, level of cognitive engagement and willingness to persist (Pintrich & De Groot, 1990; Pintrich et al., 1993; Pintrich & Schrauben, 1992). These researchers also emphasize that understanding student motivational beliefs about themselves as learners and the roles the beliefs play in classrooms can assist in understanding when and why students undergo conceptual change (Pintrich et al.). For this reason, student motivational beliefs are of interest in this study.

Contemporary cognitive theories of motivation emphasize goals and goal-orientation in attempting to interpret student patterns of achievement behaviour in academic settings (McInerney, 1995; Pintrich & Schunk, 2002). Goals are motivating forces which guide the self-management of student learning and achievements (McInerney, 1995; Volet & Chalmers, 1992). Two goal orientations have received special attention, learning and performance (Dweck & Leggett, 1988). Students with a learning goal orientation tend to seek deep knowledge, skill and competence (Ames & Archer, 1988) and to be able to use cognitive and metacognitive strategies to deal with any challenges in a learning task (Graham & Golan, 1991; Pintrich & Garcia, 1991). They are more likely to attribute success and failure to effort than ability, and to have a sense of self-competence (self-

efficacy) (Pintrich & Schunk, 2002). Students oriented by performance goals tend to establish their self-worth by seeking to outperform others (Ames & Archer, 1988). Therefore, they often avoid challenging tasks and prefer to use surface strategies and rote memorization (Ames, 1992). Learning and performance goals are not however mutually exclusive. Research evidence shows that students may have both of these goals in varying degrees depending on the 'nature of tasks, the school environment, and the broad social and educational context' (McInerney, 1995, p.157). Authority structures in the classroom and teacher evaluation focusing on competition, social comparison and external rewards foster a performance goal (Ames, 1992). Challenging, meaningful and authentic tasks will enable more students to use learning goals (Ames, 1992; Meece, 1991).

Compared with goals which are more cognitive, situational interest and value beliefs are more stable and personal. Therefore, they may be at a different level of analysis than are goals and goal orientation (Pintrich et al., 1993). Students might have multiple goals operating due to differential interests and value beliefs. For example, students may be interested in certain topics, but they may also value them because of their importance in future career options. These differential interests and value beliefs could lead to either learning or performance goal orientations (Krapp, Hidi, & Renninger, 1992). Pintrich and Garcia (1991) have shown students who perceive their course material as more interesting, important and useful to them tend to use deeper processing strategies like elaboration and metacognitive control strategies. In this study, student motivational beliefs and their impact on student learning will be explored. Strategies to promote student learning interest will be explored in the intervention.

3.4 Pedagogies related to the teaching and learning of biology

In the senior high school biology classroom, the traditional teaching approach of transmission has been found to give rise to the impression that science is static and pre-determined (Roth & McGinn, 1996). It seems that an absence of dialogue promotes the use of memorization and rote learning as productive learning approaches for student in biology (Lock, 1998). Moreover, content is often taught isolated from contexts which imbue it with relevance and meaning (Yager &

Tweed, 1991) so that students are often not able to make connections between theory and real life situations (Leonard & Chandler, 2003; Solomn & Duveen, 1994). In contrast to such a teacher-centred approach, student-centred and student-active teaching approaches are advocated as a way of helping students learn in a meaningful way (Driver & Bell, 1986; Lord, 1998). In these approaches, students are helped to understand how biology relates to them and to integrate what they learn into their daily life (Reiss, 2005; Strage & Bol, 1996). Alongside this, inquiry activities that allow students to construct new framework of the world based on their own observations and reflection are recommended (Leonard & Chandler, 2003).

Any discussion of student learning also needs to take into account how this learning is assessed. Senior biology assessment often stresses skills such as factual recall (Lock, 1997; Reiss, Millar, & Osborne, 1999). It tends to include questions restricted to contexts designed to ensure marker reliability (Reiss et al.). Student familiarity with applications of biological knowledge is rarely rewarded. When student biology learning is evaluated based on rote memorization and reiteration it is hard to expect students to achieve genuine understanding (Lord, 1998). This situation has led to a recognition that assessment needs to be extended to reflect a broad range of learning and cognitive outcomes (Dearn, 1999).

In biology classes, laboratory activities have tended to play a central role in teaching (Treagust, 1991). However, there is some evidence that biology laboratory classes are not often used with senior biology classes (Gardiner, 1999; Solomon & Duveen, 1994). There are many possible reasons for this, for example, the difficulty of obtaining living organisms (Lock, 1998) and time constraints caused by an overcrowded curriculum (Lock, 1994). In addition, biology laboratories are perceived by some teachers as ineffective, mainly because they are confirmatory rather than investigative (Gardiner, 1999). Students in these confirmatory laboratories are passive (Lock, 1998) and thus have limited opportunities to engage in the learning process and develop skills in thinking, discussion, debate or research (Thair & Treagust, 1997; Paturungi, 1991). It appears that when students have the opportunity to engage in open-ended investigations that allow them more autonomy in defining problems and methods,

and arriving at solutions, these can contribute substantially to their understanding of the nature of science (Hodson, 1988). Research indicates that inquiry-based instruction can enhance student learning significantly, such as in increasing student interest levels, ability to solve problems (Paris, Yambor, & Packard, 1998), science skills and achievement, and student attitudes toward science (Chang & Mao, 1999).

This section provides an overview of what research has to say about the problems of student learning and the strategies and pedagogies that might assist students to improve their biology learning in order that the study builds on what is known. Research on student alternative conceptions that can help in understanding the ideas student bring to class is outlined, along with strategies that have been found helpful in enhancing learning. These strategies include teaching approaches for promoting conceptual change, Socratic teaching approaches and group work learning approaches. Assessment for learning is outlined and the essence of open investigations in practical work elucidated. The possibilities of these pedagogical approaches for interactive teaching and the use of open investigations in biology are of concern in this thesis.

3.4.1 Thinking about alternative conceptions and the nature of science

In the light of the constructivist views of learning, before children have been formally taught science, they have already developed their own ideas and beliefs to make sense of the world (Driver, Asoka, Leech, Mortimer, & Scott, 1994). These student ideas and beliefs are often inconsistent with scientific knowledge and they have been found to affect further learning. Science teachers need to be aware of this and find out about student alternative conceptions. In the classroom, depending on their own view of science, science teachers have different approaches to taking into account the student alternative conceptions. Those with an objectivist view of science are likely to judge student ideas as wrong (Grandy, 1997). This view is exemplified in the use of terms such as ‘erroneous concepts’ (Matteson & Kambly, 1940); ‘erroneous ideas’ (Champagne, Klopfer, & Anderson, 1979); ‘misconceptions’ (Viclund, 1940); ‘mistakes’ (Grown, 1983); ‘naïve beliefs’ (Matthews, 1998); and ‘misunderstanding’ (Brumby, 1979) to describe student ideas. Science educators/teachers with an evolutionary

perspective of science (West, 1982) drawing on Kuhn (1970) and Toulmin (1967), are more likely to be tolerant of student existing knowledge when it is inconsistent with accepted conceptions. Two categories of terms are used to describe student knowledge from this view. The first category includes terms with a neutral connotation, such as 'existing conceptions' (Nussbaum, 1979) and 'prior conceptions' (Posner, 1982). The second category which includes terms with a tolerance for existing conceptions includes 'alternative conceptions' (Hewson, 1981), 'alternative frameworks' (Driver & Easley, 1978) and 'alternative ideas' (Engel & Driver, 1985). These researchers agree that student conceptions of natural phenomena have their own value (Driver, 1983). In this study, student conceptions will be acknowledged and guided to link to biologists' conceptions.

Not only do students have alternative views of biology concepts, they also have different views of the nature of biology. For example, they may see some ideas as fixed or unchanging. The researcher in this study recalled when she studied in junior high school, she was taught that the pathogen of trachoma (a type of eye disease) was a virus and the divisions of organisms were three kingdoms (animal, plant and bacteria). By now, the prevalent near world-wide shibboleth has been to maintain that the pathogen of trachoma is a bacterium and the divisions of organisms are five kingdoms (animal, protozoa, plant, fungi and bacteria). Based on instances like this, the current consensus is that a more nuanced appreciation of the nature of science will allow richer and more valid ways for biology teachers to teach and students to learn. Reiss and Tunnicliffe (2001) proposed that student appreciation of the nature of science is important because whether or not they go on to use science an understanding of what science is and the ways in which it operates is of value to all people as citizens and consumers. This discussion shows that biology teachers need to help students to appreciate the evolutionary nature of biology knowledge and the certainties and the uncertainties about biological issues. They also need to take into account student alternative conceptions. Teaching approaches to accomplish this are discussed next.

3.4.2 Promoting conceptual change

Learning can be seen as conceptual change (Hewson, Beeth, & Thorley, 1998). The purpose of biology teaching is to help students develop and use appropriate

scientific conceptions and to socialize them into the biological science community. This section sets out ideas to do with teaching for conceptual change consistent with this goal.

Over the last two decades of the twentieth century, an extensive literature has grown on the development of children's concepts. One of the most influential models of conceptual change has been developed by Posner et al. (1982). They hypothesized how individuals make choices among competing or alternative views, models or theories of the natural world and suggested that four conditions are necessary for an accommodation to occur in an individual's understanding. The four conditions are; dissatisfaction with existing conceptions, and intelligibility, plausibility, and fruitfulness of new conceptions. An individual's existing concepts and the relationship between them, that is their conceptual ecology, influence the selection of a new central concept. The model raised by Posner et al. was critiqued on the basis that it assumes learners have well-articulated conceptions or misconceptions about most topics and that it is too linear and rational. In response, Strike and Posner (1992) proposed five modifications to the original model as in the following:

- (1) a wider range of factors needs to be taken into account in attempting to describe a learner's conceptual ecology. Motives and goals and the institutional and social sources of them need to be considered. The idea of a conceptual ecology thus needs to be larger than the epistemological factors suggested by the history and philosophy of science;
- (2) current scientific conceptions and misconceptions are not only objects on which a learner's conceptual ecology acts, they are themselves parts of the learner's conceptual ecology. Thus they must be seen in interaction with other components;
- (3) conceptions and misconceptions can exist in different modes of representation and different degrees of articulateness. They may not exist at all but may easily appear to do so, because under instruction or in research they are generated by other elements of a conceptual ecology;
- (4) a developmental view of conceptual ecologies is required; and,
- (5) an interactionist view of conceptual ecologies is required (p.162-163).

In the revisions of the theory, two points were emphasized. Firstly, conceptual change is dynamic and developmental. Secondly, conceptual change involves social and contextual factors.

Student prior conceptions have been found resistant to change with instruction (Ross, 2001). Vosniadou (2001) suggests that one reason for this is that misconceptions are linked to fundamental presumptions about the ontology and epistemology of the physical world. Therefore, a revision of a scientific concept requires a revision of fundamental presuppositions and beliefs. Chi (1992) pointed out that the extent to which children's conceptual change occurs depends on the nature of the concepts involved. She deemed that conceptual change can be divided into 'within' and 'across' ontological conceptual change. The former means that a concept shifts to another concept within the same category, which is easy and frequently happens. The latter means that a concept from one category shifts to another, different category. This is not easy and less frequently happens. When the student existing knowledge and the knowledge they are going to learn are compatible, the two kinds of knowledge have shared attributes, therefore conceptual change occurs (Chi, deLeew, Chiu, & Lavancher, 1994). In contrast, without co-shared attributes in concepts, conceptual change is hard; a similar situation to that of scientific revolution within science itself (Thagard, 1992). This point raises the question as to whether the children's and scientists' conceptual change are similar in the domain of science. Some researchers argue that conceptual change is similar in both practising scientists and children when they are learning science. For instance, Carey (1985) considered children's processes of conceptual change are a 'gestalt switch', which is similar to the discovery process of scientific knowledge. Other researchers disagreed (Chi, 1992; diSessa, 1993; Thagard, 1992). For example, diSessa (1993) believed that novices' intuitive knowledge based on superficial interpretations of physical reality is partial knowledge in that novices' knowledge is more likely to explicate a limited set of situations rather than constitute a coherent and systematic theory. In contrast, diSessa argued that experts tend to systematically and coherently organise their knowledge into large accessible units. It seems that more researchers supported children's and scientists' conceptual change being different. The implication of

this is that before using conceptual change teaching strategies, there is a need to understand the nature of the concepts they are likely to need to be changed.

Promoting student conceptual change from prior conceptions towards more scientific conceptions is the concern of this study. Teaching strategies that emphasize the importance of student prior knowledge and meta-conceptual awareness have been shown to facilitate student conceptual development (Driver, Guesne, & Tiberghien, 1985; Vosniadou, 1994). Using these strategies requires teachers take into consideration student point of view in the design of instruction. To do this, teachers need to be informed about how students see the physical world. Teachers need to understand the nature of the intended concept and student prior conceptions so they can design appropriate teaching activities to promote meaningful learning (Driver et al.). These activities need to accentuate the connection between the science instruction in school and activities outside school because students need to link their prior experiences to scientists' concepts (Vosniadou, 2001). Teachers are supposed to provide students with experiences to help them understand the limitations of their current interpretation of phenomena. To do this, Vosniadou suggested teachers can make use of discrepant events to make students dissatisfied with their current ideas, and hence prompt students to consider replacing them with a better alternative. Another suggestion is that in teaching for conceptual change, teachers need to create learning environments that encourage peer discussion and the verbal expression of ideas. Through discussion, students make their interpretations of phenomena explicit and engage in negotiations of meaning that make their ideas available for reflection and review (Champagne, Gunstone, & Klopfer, 1985). While these activities can be time consuming, they have been found to be indispensable for ensuring that students become aware of what they know and understand what they need to learn. In addition, group discussions generate alternative conceptual schemes because different students offer different perspectives (Driver et al.). These perspectives bring cognitive flexibility for students (Vosniadou, 2001). Laboratory work can be successfully used to promote conceptual change but only when time is spent in interacting with ideas rather than interacting with apparatus, work sheets and teaching instruction (Gunstone & Champagne, 1990). These four teaching strategies of teachers finding out about student ideas, making use of discrepant

events to lead to conceptual change, and providing students with opportunities for interactions were employed in this study to help student conceptual change. In the next section, the Socratic teaching approach that helps students to find out about their own misconceptions and make conceptual change is introduced.

3.4.3 Socratic teaching approaches

To help students find out about their conceptions and to change them, effective teaching approaches are needed. The Socratic teaching method is one such approach. Socrates was the first Western philosopher and the first theorist of the meaning of education. He assumed that knowledge is innate, concealed in the souls of people, but forgotten or shrouded temporarily (Broudy & Palmer, 1965). Education is a process of recollecting or drawing out in the learner what is already there. A genuine teacher can only provide the context for students to foster their learning rather than launch learning (Hamilton & Cairns, 1961). Socrates guided his students to abandon the pretence of knowing so they were able to think about a question at a more fundamental and original level. His educational theory focused on a dialogical method of interactive learning, in which he employed an approach of questioning that encouraged thinking.

According to Socratic philosophy, students do not acquire knowledge through picking up bits of information didactically conveyed to them. Only when they undertake reasoning and make entirely explicit to themselves the reasons for the correct answer will they attain knowledge (Nola, 1997). Consequently, the art of question posing is an essential component of Socratic teaching methods. Teachers employ a diversity of questions to stimulate student thinking to pave the way to discover truth (Brogan & Brogan, 1995). Deeper questions serve to facilitate student higher-order thinking skills and reveal their genuine understandings of subject matter (Watts, Alsop, Gould, & Walsh, 1997). In science, higher-order thinking skills can be a source of new hypotheses, they can provide the means for testing hypotheses, and they can convince people why one belief ought to be held rather than another. Thus, higher-order thinking skills are crucial in science education (Nola, 1997).

Within the Socratic Method, learning is a social event and cannot occur unless both the teacher and students are personally involved in the process. If the teacher does not show curiosity and interest toward the topic they are going to teach then students will not be enthusiastic to learn. Like Socrates, the teacher should pretend ignorance to encourage the students to teach him/her to initiate the process of inquiry (Brogan & Brogan, 1995). Watts et al. (1997) regarded meaningful dialogue as a diagnostic tool to determine what sense students are making of the content of instruction and to recognize conceptual change. Meanwhile, through the dialogue, the student misconceptions are revealed (Julian, 1995) and they are taught to sense the power of being intellectually challenged to consider others' perspectives and to test their own views in the light of these perspectives (Brogan & Brogan, 1995). Within the dialogue it is a good strategy for a teacher to adjust their questions to students and responses to the intellectual needs of students and to respond to all answers with a further question. As well, the teacher needs to link ideas together to make the teaching content a whole picture (Elder & Paul, 1998). In addition, a teacher should encourage interruptions triggered by curiosity and engagement from the students (Watts et al.). Rop (2002) advised that these events come quickly with a short life span, so if the teacher does not grab the opportunities in time, an important teaching moment may be lost forever.

Although Socratic teaching approaches promote intellectual work, they have several weaknesses. First of all, they are time consuming. Secondly, students might provide expected answers rather than the ones coming from real understanding. Lastly, this approach is not suitable for every student. Certain students feel harassed by intensive questioning or dislike that they need to exert themselves to bring forth a thought (Julian, 1995). However, when the intention is to find out student alternative conceptions, facilitate their thinking and help them reflect their own ideas, Socratic teaching approaches are very effective and so they will be employed in the teacher-student interactions in the intervention in this study.

3.4.4 Group work approaches

Group work has long been regarded as an effective strategy to meet the current challenges of science education (Pearsall, 1992; Yager, 1991), including fostering

conceptual learning and promoting creative problem-solving (Cohen, 1994; Johnson & Johnson, 1992). Normally, groups are heterogeneous (very often in academic ability) and students play different procedural roles (Moreno, 1999), such as chief investigator, recorder-reporter, material manager and harmonizer. These roles are usually rotated among group members from activity to activity so that students participate equally. This reduces, but does not eliminate, the probability that one person will do a great deal or all of the work (Bianchini, 1997). Group work can provide more opportunities for students with a wide range of abilities to make important contributions to the group (Cohen, Kepner, & Swanson 1995; Herreid, 1998). Despite this, research has found that student status can influence their access to discourse during group work and thus their learning of science (Cohen et al.; Cohen & Lotan, 1995). Students with high status talk more, have greater access to materials, and consequently, learn more. In contrast, students with low status may participate and learn less than their high-status counterparts (Cohen, Lotan, & Leechor, 1989; Lotan, Cohen, & Holthuis, 1994).

In this study, group work was adopted to encourage students to have more interactions with each other and to participate in knowledge construction equally.

3.4.5 Assessment for learning

Constructivist views of learning recognize that students construct their own ideas. Therefore, teachers intending to improve student learning need to have some idea of how and what students are learning (Willis, 1994). Given students' individual differences, there is a requirement that the teacher use different modes, as appropriate for individual students, to gather information for this (Crooks, 1988; Stiggins, 1995). For instance, teachers can observe and/or provoke classroom dialogue by questioning students during whole class, small group, individual discussions and laboratory work (Bell & Cowie, 2001). Open questions and an increase in wait time for student responses can enhance the quality of assessment information (Rowe, 1987). During interactions a teacher can provide students with on-the-spot feedback. Productive feedback includes information to help student move their learning forward. Self-assessment, emphasizing student thinking and metacognition, is also a way of eliciting assessment information (Parkin & Richards, 1995). This has the potential to increase student involvement in

assessment of their learning, which is congruent with constructivist views of learning (Bell & Gilbert, 1996). Student commitment to learning will be enhanced, if they are responsible for their own progress and improve their learning by reflection (Fairbrother, Black, & Gill, 1995; Klenowski, 1995). For this to happen, students require an unambiguous overview of what they are expected to learn (Black, 1995; Klenowski, 1995).

Acting on the interpreted information is centred to assess for learning. Because there are different individual understandings among students, it is not easy for teachers to take effective action (Torrance, 1993; Savage & Desforges, 1995). It seems that a teacher's attention is often focused on class progress rather than individual achievement due to their responsibilities to teach a curriculum (Bachor & Anderson, 1994). Planned actions and teacher flexibility are crucial for assessment for learning and differentiated learning experiences (Black, 1995; Harlen & James, 1996). A teacher can provide their students with more experiences and move on to the next topic and/or re-explain the topic (Gipps, 1994). Teachers who have judged students as having a diversity of understanding have been found to provide their students open work allowing for multiple outcomes (Sutton, 1995).

In short, assessment for learning is an important part of effective teaching and learning when learning is viewed as a constructive process aimed at conceptual change; hence it was incorporated into the intervention in this study.

3.4.6 Wider possibilities for practical work and investigations in school science

Practical work (the terminology used in the UK) and laboratory experiments (the terminology used in the USA) refer to experiences in schools in which students interact with materials to observe and understand natural phenomena and to gain first-hand experiences. In biology education, process learning outcomes and student experiences with, for example, manipulation of apparatus, are also seen to be valued. These skills and understandings can be developed mostly through practical work in biology laboratories (Wellington, 1998). This section focuses on

practical work and then the scope is narrowed down to investigations in school science.

Practical work in school science

This section sets out a history and critique of practical work in school science. It outlines reasons for the incorporation of practical work into school science, details the range of types of practical work and discusses the openness of investigation.

- **Historical perspectives**

An excursion into the history of science education shows that practical work became a part of science education in the mid-1850s (Gee & Clackson, 1992). During that era, it was mostly performed by the teacher and was considered as a means of illustrating concepts. Early in the twentieth century, those who supported practical work advocated students learn specific skills to discover things for themselves and laboratory manuals acquired a more utilitarian, applied orientation. However, by the mid-twentieth century, practical work was again largely being conducted for illustrative purposes. Subsequently, three important movements in science education, namely the discovery approach, the process approach, and constructivist approach (Hodson, 1996b), have shaped its role.

At the beginning of the 1960s, the major science curricula aimed to engage students in investigation and inquiry and expected students would discover conceptual knowledge through activities designed to mimic scientific inquiry. The Nuffield programme in the United Kingdom (UK) and the BSCS project in United States (US) were developed on this premise. Both emphasized that the learning of science best achieved through observation and experiment and by inquiry and discovery. In essence, these programmes were based on inductivist ideas about the nature of scientific inquiry. Laboratory work was central to both the curricula as a means of obtaining factual information, from which conclusions and interpretations would be drawn. It was assumed these data were objective and led to reliable knowledge of the world (Hodson, 1996b). The inductivist Baconian view of science inherent in this discovery learning is now regarded as inadequate (Millar & Driver, 1987; Duschl, 1988). It has been abandoned by philosophers and sociologists of science. Furthermore, discovery learning is pedagogically

unworkable; students cannot discover something they are conceptually unprepared for and many experiments fail to provide the results required to meet curriculum goals related to content (Hodson, 1996b).

In the late 1960s in the US, and in the 1970s in the UK, the process approach was adopted. The assumptions underpinning the process approach are that science is a discrete, context-independent, generalized and transferable process; science knowledge is considered to result from the engagement in the process. Students are able to conduct scientific inquiries by practising and developing scientific skills which can be readily observed and precisely and reliably measured (Hodson, 1990). The process approach was based on the myth that the skills and processes of science could be disengaged from the knowledge base and were transferable and universally applicable (Wellington, 1998). It contributed to a series of curriculum initiatives based on the belief that the acquisition of particular conceptual knowledge was largely subordinate to understanding and developing the skills and techniques of scientific inquiry (Woolnough, 1988). These initiatives included Warwick Process Science (Screen, 1988) that was developed in the UK and the Science - A Process Approach that was developed in the USA (American Association for the Advancement of Science, 1967). It is now argued that it is impossible to engage in the processes independent of content and the ways one classifies, measures and hypothesizes, and one's level of sophistication in doing so, depend on theoretical understanding (Hodson, 1996b). Apparently, theoretical considerations are requisite to, and precede, experimental inquiry (Hodson, 1990). In addition, students who can carry out de-contextualized tasks successfully are unable to integrate these skills and abilities into a coherent and effective strategy for scientific investigation (Hodson, 1992a).

A constructivist approach to practical work was prevalent during the 1980s and 1990s. This approach emphasized both scientific content and processes in terms of constructivist views of learning (Hodson, 1992b). When students interact with ideas that they perceive to be meaningful based on their prior experiences, they can construct the current understandings of scientific concepts. This needs students to interact with the expert community (teachers, textbooks, and knowledgeable peers, etc.) to ensure the knowledge they construct is generally

consistent with the knowledge developed by the scientific community (Lunetta, 1998). For effective learning about how to do science, it is important that there is a trusted and skilled teacher to guide students (Gil-Perez & Carroscosa-Alis, 1994). With the teacher's assistance, student conceptual understanding and procedural knowledge both increase and students are helped to become responsible for their own investigations. Learning science is not merely an 'individual making sense of the world' (Biddulph & Osborne, 1984), but involves 'what and how science knows' (Hodson, 1996b). In other words, process and product are interdependent and intertwined in learning science (Metz, 1995). Also learning science is contextualised (Brown, Collins, & Duguid, 1989). It is inappropriate to see science as discrete and content-free processes; rather it is a theory-driven activity (Hodson, 1996b). Researchers have argued that the thought of having one format or one algorithm for science is flawed (Wellington, 1998). No fixed scientific method can be applied to all investigations. The nature of scientific method depends on the context that scientists are in; scientists choose a method which is appropriate to a particular situation and so the scientific method is not a set sequence of steps, but rather is experience-dependent. In investigations, students reflect their progress and are provided opportunities to gain insight into the idiosyncratic and reflexive nature of scientific investigation (Hodson, 1996b).

- A critique of practical work in school science

Many science educators assume that carrying out practical work assists students in their learning science. For this reason, science teaching taking place in laboratories has been accepted without serious query. However, since the late 1970s, the nature and value of practical work in science teaching and learning has increasingly been examined and questioned (Bates, 1978; Hofstein & Lunetta, 1982). That learning science itself is best approached by doing science in the laboratory is disputed considerably, and researchers have moved to re-evaluate the role of practical work in science education (Hodson, 1996a). The notions that practical work is a good tool for teaching theory and that it is of little educational value have both been proposed (Chapman, 1993; Leach & Scott, 1995; Wellington, 1989; Hodson, 1990; Hodson, 1996b).

Critiques of practical work are that only in the development of laboratory manipulative skills does it have a conspicuous advantage over other modes of instruction (Bates, 1978; Hofstein & Lunetta, 1982). Another suggestion is that assessment very often emphasizes low-level skills which encourage students to concentrate on manipulation rather than connecting theory and practice. In some cases, it is possible for students to do well in assessment without even attending a laboratory (Boud, Dunn, & Hegarty-Hazel, 1989). Many researchers reported that most students in laboratories attained little insight either into the main science concepts involved or into the process of knowledge construction (Bodgen, 1977; Waterman, 1982; Novak, 1988). Hodson (1998) argued that the very first-handedness of practical work may serve to distract the student from significant conceptual issues. The worst-case scenario is that students leave the class more confused than when they arrive (Beaver, 1999). On the other hand, Linn (1997) highlights that practical work provides students with the opportunity to become actively involved in the scientific process. Hazel and Baillie (1998) assert that practical work can be worthwhile, whether this is so depends on whether students work on their own and undertake work of an investigative nature. Howe (1996) declares ‘There is always the danger that the concept learned in school will remain a verbalism rather than a true concept unless or until it is applied to situations or phenomena encountered by students in their everyday life’ (p.40). The need for authentic science activity such as practical problem-solving is highly stressed by many researchers (Woolnough, 1998; Watts, 1991). In the intervention, an observation activity was conducted in an investigative way to enable the work to be worthwhile; also problem-solving activities were designed to help students construct true concepts as researcher stressed.

- **Reasons for incorporation of practical work into school science**

School science is embedded in the laboratory which is regarded by academics as the place where students should do what scientists do by experiments, but it is also used to develop the manipulative skills of students, to exemplify a theory, provide an alternative model for understanding and to acquire knowledge and conceptual understanding (Dawson, 1994). An array of earlier research has articulated the reasons for incorporating practical work into school science (Kerr, 1964; Hodson, 1990; Wellington, 1998). These reasons include enhancing

cognitive development, investigative and social skills and supporting motivation and scientific attitudes. They are discussed in the following sections.

Practical experience of phenomena is essential for acquiring and developing student understanding of scientific concepts (Hodson, 1996a), such as photosynthesis (Brown, 1998; Chan, 1996), heredity (Heckman, 1992), and osmosis (Morse, 1999). According to Kerr (1964), practical work is able to verify, affirm or elucidate facts and principles already taught and make biological phenomena more real through actual experience. Practical work also promotes the understanding of the interplay of theory and methodology (Hazel & Baillie, 1998). It allows students to get a general sense for phenomena (Wellington, 1994, 1998) and apply abstract ideas to concrete situations (Beatty & Woolnough, 1982; Bucat & Cole, 1988).

However, some researchers disagree that practical work can enhance student cognitive development. A counter argument was made by Berry, Mulhall, Gunstone, and Loughran (1999). They investigated secondary school students' perceptions of laboratory work. Although the students said it helped their understanding of theory they had previously learned, they observed little evidence that the students had reflected on the value of observations and/or tried to link them with prior knowledge. According to this point of view, practical work does not automatically promote conceptual understand. Teachers need to work to improve their student use of process in ways that will contribute to their learning. This is also a concern of this study, which seeks to investigate the potential of practicalwork develop students' understanding.

Laboratory skills are concerned with the doing of science (Hodson, 1996a). Research indicated that practical work promotes the process of scientific thinking (Lucas, 1971; Raghubir, 1979; Hofstein & Lunetta, 1982); hence laboratory skills are not only manipulative or manual dexterity skills, but also higher-level transferable skills which are defined in more detail as the ability to:

- (1) generate own ideas, hypotheses and theoretical models and/or utilize those postulated by others;
- (2) design investigations, experiments, trials, tests, simulations and operations;
- (3) conduct investigations, experiments, trials, tests and operations; and,

- (4) evaluate data and results from the processes and outcomes of investigations, experiments, trials, tests and operations (Gott, Duggan, Millar, & Lubben, 1995, p.187).

These descriptions are concerned with the understanding needed to put science into practice and is actually ‘the thinking behind the doing’ which is complementary to conceptual understanding (Gott et al., 1995).

Encouraging the development of social skills is regarded as one of the main aims of doing practical work in school science (Hodson, 1996a). Wellington (1994) considered the main social skills are communication, interaction and cooperation which include debating with group members, and then convincing them or negotiating with them to develop a shared interpretation. Also, he argued that dominant group members, competition, a lack of engagement for someone and a division of tasks might enable the claim that practical work enhances social skills to be partially true. Hodson (1990) declared that those skills were prerequisite to engage successfully in practical work; however, practical work was not indispensable to provide students with those skills. He advised school educators to be cautious in the selection of which skills to teach.

Practical work can stimulate the work of a real scientist (Kerr, 1964), motivate students by stimulating interest, enjoyment and excitement (Hodson, 1996a), arouse curiosity (Beatty & Woolnough, 1982; Bucat & Cole, 1988), and develop student imagination (Boud et al., 1989) and creativity (Hofstein & Lunetta, 1982). However, Hodson (1990) comments that practical work might not entail motivational value unless students are provided with the experiments to evoke their interest and allow them to do autonomous investigation. In the intervention, open investigations which allow students having more autonomy are designed to enhance their attitudes toward learning biology.

Practical work can also inculcate scientific attitudes. Scientific attitudes, being distinct from attitudes toward science, are approaches and attitudes toward information, ideas and procedures regarded as being indispensable for doing science, such as objectivity, open-mindedness (Hodson, 1990) searching for data and their meaning, and respect for logic (Simpson, Koballa, Oliver, & Crawley,

1994). Both attitudes toward learning science and scientific attitudes are considered as important within this study.

What follows, is an outline of the different types of practical work and the features of practical work that has been found to have a positive impact on student interest motivation and learning.

- Types of practical work

There are five types of practical work, as classified by Hazel and Baillie (1998): teacher demonstrations; controlled exercises; structured investigations; unstructured investigations; and projects. Demonstrations are for showing the features of a piece of equipment, how it works, providing students with a vivid experience of science and advancing their understanding of scientific concepts (White, 1996). In controlled exercises, students are expected to arrive at a predicted outcome. Although the controlled exercises have practicality and reliability, they can be tedious and have little cognitive challenge; so students do not show much enthusiasm (Hodson, 1990). Investigation can be more or less structured. In structured investigations, the control of the desired aim is retained for the teacher, materials are given all or part, and methods are part given or open. In unstructured, open investigations, students decide everything except the aim of investigation. Open investigations provide students with a good motivational context and opportunities to practise scientific enquiry (Hazel & Baillie, 1998). Nevertheless, open investigations have been criticized for taking too much time, energy and expense, and for being too risky. The suggestion is that students may not possess the abilities required to cope with such a lack of structure and feel lost (Costenson & Lawson, 1986) and teachers can be poorly prepared. Student team work and staff development are suggested for improving the weaknesses of investigations (Hazel & Baillie, 1998). In projects, the final of Hazel and Baillie's categories of practical work, teachers hand over development of the aim, and control material and method and predictability in the laboratory. The work of projects most closely simulates real life and helps students apply prior knowledge to new problems. In this context, students need to stretch themselves beyond the simple tasks of memorization and solve problems by developing/adopting their own strategies (Ghosh, 1999). The benefits of projects include the individualized

learning, the establishment of a sense of responsibility and commitment to the work, and the practise of oral and written communication skills. The disadvantages of investigations and ways of improving them can also apply to projects (Hazel & Baillie, 1998). A summary of Hazel and Baillie’s categories of practical work is shown in as follows.

Type of laboratory	Level of enquiry	Definition of level			
		Aim	Material	Method	Answer
Demonstrations	0	Given	Given	Given	Given
Controlled exercises	1	Given	Given	Given	Open
Structured investigations	2	Given	Given all or part	Part given or open	Open
Unstructured investigations	3	Given	Open	Open	Open
Projects	4	Open	Open	Open	Open

Table 3.1: The level of openness for scientific enquiry in different laboratory exercises (Hazel & Baillie, 1998).

To understand and improve student learning of biology, it is necessary to consider carefully the types of experiences and experiments offered to students. At the time of the research, teacher demonstrations and controlled exercises were predominant in teaching conducted by biology teachers in Taiwan. They were closed-type experiments. In the intervention for this study, more open investigations were used to facilitate student cognitive development.

Investigation in school science

An investigation is defined by Monk and Dillon (1995) as ‘an activity in which students use the processes of science to build knowledge which is new to them’ (p.73). The desired goal is that students are able to appreciate how science is actually done and understand how biology is related to the world outside the classroom and laboratory (Ghosh, 1999). Doing investigation could be considered as a good pedagogic method to attract student minds and encourage their thoughtful participation (Millar & Driver, 1987). However, these gains are premised on an open-ended investigation.

In an open-ended investigation, students can decide the apparatus they prefer to use and the observations or measurements they would like to make, with the focus on scientific ways of working rather than on achieving the predicted outcomes that textbooks present (Millar, Lubben, Gott, & Duggan, 1994). Open investigations encourage students to use their initiative and prior experience to solve problems. The experiences of solving problems enhance student learning of knowledge and understanding and their investigative strategies (Jones, Simon, Black, Fairbrother, & Watson, 1992). Many educators used the classroom management of open-ended investigation tasks to allow students more freedom to define the problem, method, solution and extensions (Jones et al.; Sundberg & Moncada, 1994; Germann, Haskins, & Auls, 1996).

- The openness of investigation

When doing an open investigation, students react continuously in thinking through observing, hypothesizing, discussing, experimenting and reassessing their hypotheses in the light of outcomes. Through investigative activity, students are expected to develop general practical problem-solving strategies based on the knowledge already possessed and to apply them in a new context (Watson & Fairbrother, 1993). An open investigation requires students to engage in thinking. The more open the investigation, the more difficult it is (Monk & Dillon, 1995). However, not all investigations need to have a similar degree of openness. The amount of openness that is appropriate will depend on student previous experience and present needs, and on the aims of a particular series of lessons. If students need more direction, teachers can offer more closed activities. If teachers wish their students to be given more initiative, they can make the work more open (Jones et al., 1992).

Investigation can be more or less structured and hence more or less open. Jones et al. (1992) suggested considering open work as science activities with different degrees of openness. They are; the openness in defining the problem, choosing a method, and arriving at solutions to a problem of an activity are demonstrated.

In the first phase of defining the problem, the more prescriptive statements of the investigation are given to students, e.g. what the variables are and how they can be

operationalised, the more closed the activity is. In the second phase of choosing a method, the openness depends on the choice of means that students are allowed to carry out an investigation. If the students are told what to do or the capability of the apparatus provided is limited, the investigation is more inclined to the closed end of the spectrum. The extent to which an investigation is related to other work is another factor that can affect the variety of methods available to be chosen and used. If students had already done an investigation of a specific topic, then the methods may already be defined to some degree. In contrast, closed tasks can be opened up by providing students with a choice of methods. In the last phase of arriving at solutions to a problem, a more open investigation has many acceptable solutions. An acceptable solution needs to be consistent with the way in which the investigation has been defined and operationalised. In other words, students may reach a variety of solutions depending on which variables they explored and how they performed their investigations (Jones et al., 1992).

In considering how teachers might implement an investigation in class, Jones and Kirk (1990) proposed a framework for structuring lessons involving investigations consisting of five stages; focusing, exploring, reporting, consolidation, and applying. In the stage of focusing, the teacher stimulates the student interest and focuses their attention on the important features of the investigation. In the stage of exploring, the students perform the investigation to attempt to answer questions they may have, and to further explore their tentative statements. In the stage of reporting, the students report what they have found out about their particular investigation and are allowed to question each other about what they have found. In the stage of consolidation, the teacher and the students use the information gained to further develop knowledge and understanding, and process skills. In the last stage, the students perform further investigations using the newly developed ideas and further information provided by the teacher and/or using their ideas in more formal written exercises. This framework will be adapted to support the open investigations of intervention for structuring lessons.

Watson and Fairbrother (1993) suggested some useful tactics for teachers to use to manage investigations. First of all, organise groups in the laboratory. The students are divided into groups for sharing ideas and for performing the investigation.

Once this is done, students work individually to write a report. Secondly, the teacher offers guidance by providing questions, verbally or on written work sheets, designed to help students make their ideas more explicit and to help them develop process skills, knowledge and understanding. This process can also be useful to elicit what the students are thinking about during the activity. Lastly, students need to manage resources. They plan ahead and order the apparatus that they will need. It is hard to predict what apparatus the students will be in need of and not to supply them with too much equipment, as they may think they have to use all the equipment. These tactics will also apply to the open investigations of intervention.

3.4.7 Summary of pedagogies for enhancing teaching and learning in biology

The pedagogies discussed are expected to be able to contribute to this study mainly through promoting student understanding and improving student learning and classroom practice. These pedagogies have the potential to assist teachers to find out student misconceptions and then help promote student conceptual change. This is important because student prior conceptions might be different from scientific conceptions, which is known to lead to student problems in learning biology. In learning biology, concepts research indicates the Socratic teaching approach can be helpful because it not only facilitates student reflection on ideas but it is also effective for gaining insight into student prior concepts and promoting conceptual change. Student alternative conceptions are tolerated and/or appreciated within this approach which can encourage them to construct their own meaning of the natural world. Through group work, knowledge is constructed socially by debating or exchanging opinions. By adopting a variety of assessment for learning techniques, student performances can be evaluated and built on so that their learning is improved, and both teaching and learning of biology are integrated.

When students achieve outcomes from carrying out investigations, if the outcomes are as they expected, research indicates that assimilation will occur. However if there are unexpected outcomes from a student perspective, reinterpretation is required and needs to be encouraged. In this case conceptual change towards more scientific concepts can occur with teacher assistance. During the process of learning biology, meaningful learning of concepts is more likely to happen if

students can observe phenomena through manipulation and are encouraged to think deeply and reflect on what they have done. However, all observation is theory-dependent. What students see is dependent to some extent on the theories which they hold. They need to have some expectations about what is likely to happen. These expectations then act like scripts which enable them to predict and act. With the guidance of a theory, useful knowledge can be derived from an observation. Without it, students might be distracted and/or miss relevant data. In learning biology, students are required to attain a framework of biological facts and should be given the opportunities to propose, design and carry out investigations specifically to provide grounds to help them refine their ideas and construct their meaning of these facts. Nevertheless, the development of these skills cannot be separated from some specific concepts. Open investigations can encourage students to use and develop process skills and provide students with opportunities to learn actively and experience authentic scientific work. Through such activities, students can clarify their ideas, change their concepts towards those of scientists', think deeply, debate and negotiate with people, and then construct their own knowledge. These statements indicate there is a need for students to engage in intellectual work through the connection of underlying theory and practical reality.

In this study these pedagogies, which are associated with the social constructivist view of learning, formed the basis of an intervention intended to help students to improve their learning in biology lessons in senior high school in Taiwan.

3.5 Introducing the research aims

Students learning biology not only involves the personal construction of knowledge but also interaction within the social context and physical world. Any student interactions with their social, physical and cultural world are dynamic. These interactions include teacher-student interactions, peer discussions and the use of tools in the setting. Language is one of the tools used in interactions, one that propels student development of thought. Through interactions, students learn to use appropriate scientific language and are socialized into the biological science community. To help students with this process, teachers need to have insights into

students' alternative conceptions. Students also benefit when scientific concepts are applied to everyday life and their experience is incorporated into a scientific conceptual framework.

International research has reported the difficulties associated with teaching and learning in senior high school biology. For example, transmission approaches in teaching encourage memorization and rote learning. Confirmatory type laboratory work undermines student appreciation of the purpose and nature of biological investigations. These types of approaches also interact with and influence people's views of learning. How students come to know biology is based on their view of knowledge and associated learning approaches. Students who believe knowledge can be transmitted tend to learn passively (Baird & Mitchell, 1986) and students who believe knowledge is tentative tend to learn actively (Ryan, 1984). International research suggests that more effective biology teaching and learning is student-centred and encourages active learning approaches.

Strategies and pedagogies based on a social constructivist view of learning can assist in improving student learning by taking account of and building on student prior conceptions and incorporating the physical and social setting of their learning. Pedagogies that promote conceptual change along with Socratic teaching approaches, encouraging group work approaches, assessment for learning and the conduct of open investigation are consistent with this goal. Research suggests open investigations are particularly fruitful in helping students develop conceptual and procedural understandings. They also have the potential to provide students more opportunities to take more responsibility for their own learning.

Social constructivist views of teaching and learning require us to consider the cultural context. This study is being conducted in Taiwan. Therefore, Confucian-heritage cultures and beliefs and the associated examination culture constitute the social and cultural influences on the student biology learning in Taiwan (see Chapter 2). These need to be taken into account.

The research aims are:

- (1) To explore the existing learning and teaching situation in biology in senior high school in Taiwan.
- (2) Based on the existing learning and teaching situation and social constructivist views of teaching and learning in biology, an intervention will be designed and implemented including (a) enhancing classroom interactions for conceptual development and (b) open investigations emphasizing student autonomy and conceptual and procedural understanding.
- (3) Evaluation of the intervention in terms of student learning of biological concepts, conceptual and procedural understanding, and their attitudes.

Chapter 4

Research Methodology

This study aims to explore the existing student learning in biology in a senior high school in Taiwan and seeks to design an intervention programme utilizing interactive teaching in conjunction with open investigation to enhance students' learning in biology. This chapter sets out the research design for the study.

4.1 The research questions

Based on the research aims outlined at the end of Chapter 3, four specific questions guide this research. These are:

- (1) What is the existing learning and teaching situation in biology in senior high school in Taiwan?
- (2) Is interactive teaching feasible in the senior biology classroom in Taiwan?
- (3) Are open investigations feasible in the senior biology laboratory in Taiwan?
- (4) What is the effect of an intervention programme on student conceptual and procedural learning and their attitudes?

This chapter outlines the interpretive paradigm adopted and the main qualitative and quantitative methods used (Section 4.2), the three phases of the research (Section 4.3), the participants and techniques of data collection (Section 4.4), data analysis (Section 4.5) and considerations of validity, reliability and ethics (Section 4.6).

4.2 Methodological paradigm for research

Hitchcock and Hughes (1995) proposed that ontological presumptions lead to epistemological ones, which guide the consideration of methodology. The methodology selected will affect the research methods. This section introduces the methodological paradigm and methods fitting with the paradigm and research questions.

4.2.1 The paradigm

A paradigm is a cluster of beliefs. It dictates not only how research should be done, but also what should be studied, and how results should be interpreted (Bryman, 1988). In the interpretive paradigm investigators employ a subjectivist approach which stresses the relativistic nature of the world (Kirk & Miller, 1986). Knowledge is seen as personal, subjective and unique. This approach holds that reality is socially constructed (Berger & Luckmann, 1991) and so meaning is analysed in a social context (Held, 1980). Its aim is to discover how different individuals create, modify and interpret the surroundings in which they live (Kirk & Miller, 1986).

An interpretive paradigm is appropriate for this study. Within the chosen interpretivist framework, this study attempts to understand and interpret student and teacher perspectives as well as the interactions between student-teacher and student-student in traditional and intervention biology classes in senior high schools in Taiwan. Different participants have different interpretations based on their own perspectives and these interpretations generate multiple realities. Based on the suggestions of previous research, the perspectives of both students and teachers are of critical importance in the teaching and learning process (see Section 3.3.1). The multiple perspectives of both students and teachers enrich the interpretations of this study. The positivist paradigm was inappropriate for this study because it ignores the consideration of context and participants' perspectives and their actions.

Although quantitative and qualitative research stem from different philosophical assumptions, the former originated in positivism and the later is rooted in phenomenology (Ary, Jacobs, & Razavieh, 2002), many researchers suggest that researchers can use qualitative and quantitative research to scrutinise the different aspects of a research question (Crawford & Christensen, 1995; Greene, Caracelli, & Graham, 1989; Miles & Huberman, 1994; Neuman, 2000) and to provide a richness of data (Schwandt, 1994). The main benefit of qualitative research is that it can offer an in-depth description of human behaviours based on the participants' views in a real-life setting (Best & Kahn, 1998); whereas, quantitative research can use objective measurement and statistical analysis of numeric data to

understand and explain phenomena (Ary et al.). Qualitative research is suggested in the interpretive paradigm; however, quantitative research also can be used within this paradigm when it is appropriate to do so (Guba & Lincoln, 1989). This study employs a combination of qualitative and quantitative research.

In addition to qualitative and quantitative research, experimental research is also described by Best and Kuhn (1998) as a category of educational research. It allows a researcher to test hypotheses and reach convincing conclusions about relationships between independent and dependent variables. There are two types of experimental research, true and quasi experiments. In true experiments, participants are assigned randomly to provide for control of the equivalence of groups and of exposure to treatment. In quasi experiments, subjects are selected. In this study, because of the administrative difficulty of equating classroom experimental and control groups, quasi experiments were used to evaluate student learning. Naturally formed intact groups of students in the classroom were as subjects to compare their test achievements and perceptions of their biology classes in traditional and intervention groups after the intervention programme. Also, the intervention students were compared for their change of confidence and scientific epistemological views after the conduct of the intervention.

The qualitative data, quantitative results and experimental outcomes provided cross-method triangulation for each other. Without triangulation, the data could be open to misinterpretation. Through equally emphasizing qualitative and quantitative data, the researcher was able to gain insights into participants' perceptions and experiences. When the researcher sought to examine student and teacher perceptions of the biology lecture and experiment classes, interviews led to the generation of rich qualitative data. In contrast, quantitative data being amendable to some statistical analysis was used to explain the prevalence of some of the phenomena occurring in this study.

4.2.2 Research methods

Each research method has its own strengths and restrictions (Banet & Nunez, 1997; Griffin, 1985; Mellado, 1997). In this study, the four principal research methods adopted were interviews, observations, questionnaires, and tests.

Interviews

The interview was pioneered by Jean Piaget (Posner & Gertzog, 1982; Solomon, 1983, 1992). It is defined as a conversation between the interviewer and interviewee (or group of interviewees). The primary purpose of interviewing is to elicit research-relevant perspectives from the respondents (Barker & Johnson, 1998; Posner & Gertzog, 1982; Moser & Kalton, 1971). The interviewee's perspectives, such as knowledge, values, attitudes as well as beliefs, are gathered by direct verbal interaction (Barker & Johnson, 1998; Tuckman, 1972). A skilled interviewer is required to attain a successful interview (Patton, 2002; Posner & Gertzog, 1982). If an interviewee gives a brief answer to or misunderstands the interview question, the interviewer can motivate or direct the interviewee to respond more pertinently. Interviews allow for greater depth than other methods and are better than questionnaires for handling more difficult and open questions (Cohen et al., 2000). Because of more involvement, interviews have higher response rates than questionnaire. Moreover, there are often crucial but unanticipated perspectives generated during the process of interviewing (Oppenheim, 1992).

Based on what Patton (2002) proposed, there are four types of interview: informal conversational interviews, interview guide approaches, standardised open-ended interviews and closed quantitative interviews. The interview guide approach format was adopted in this research. The features of this type of interview are that the interviewer: outlines particular topics and issues before the interview activity; and determines the sequence and wording of questions in the interview context. The strengths are that: the data are comprehensive and data collection is systematic for each respondent based on the interviewer's outline; logical gaps in data can be forecast; and the interview is still conversational and situational. The weaknesses are: it might lead to variable responses due to flexibility, thus reducing the comparability of responses; and crucial and remarkable themes might be ignored.

The interview guide approach was adopted in this research because the conversational approach promotes student and teacher willingness in sharing their

opinions and the interview questions also guide them to specific topics and issues in the context of Taiwan.

Observations

An observation 'usually consists of detailed notation of behaviours, events, and the contexts surrounding the events and behaviours' (Best & Kahn, 1998, p.253). The observer's role may vary from completely participant to completely observer. A full participant interacts with the people being observed as naturally as possible and his/her identity is not known to them. A participant-as-observer participates fully in the group being studied and makes it clear that he/she is a researcher. An observer-as-participant is also known as a researcher but has less interaction with the group. A complete observer observes the activity of a group without any contact with the group and the subjects may not be aware of the observation (Fraenkel & Wallen, 1993). Each of the above roles has both advantages and disadvantages. The first two roles tend to be subjective but most likely to produce a detailed and comprehension picture of a group's activity. In contrast, the last two tend to be objective but might contribute to inappropriate inference because of a lack of interaction with the observed people (Fraenkel & Wallen, 1993; Cohen et al., 2000).

In this study, the researcher chose the role of participant-as-observer. The reason for this was that the researcher was also the teacher who needed to fully participate. Besides, when the participating students were asked to fill out questionnaire the researcher as teacher explained to them the questionnaires were for research purpose and irrelevant to their grades. The intention here was to make them feel secure and assure them there was no potential harm involved in their forthright.

Questionnaires

A questionnaire is a list of questions or propositions to which the respondent responds in writing. It is a widely used instrument for collecting research-relevant information. Also, it is economical based on time and money, more reliable in terms of self-administration, obtaining greater honesty due to anonymity (Cohen et al., 2000) and comparatively straightforward to analyse (Wilson, 1996). If the

researcher lives far away from the participants, questionnaires may be mailed, which resolves the problem of space-time (Cohen et al.). The restrictions of questionnaire are low return rates, having no chance to probe answers more deeply and not permitting respondents to raise additional questions which could lead to a fuller understanding of the mailed questions (Mitchell & Jolley, 1988).

There are several kinds of question and response modes in questionnaires, structured, semi-structured and unstructured. Closed, structured and numerical questionnaires are more useful with a large sample size because they are easier to analyse. Alternatively, less structured and word-based questionnaires are more appropriate for a small population (Cohen et al., 2000). More quantitative questionnaires can generate responses amenable to statistical treatment and analysis and also allow comparisons of questions across groups in the sample (Oppenheim, 1992). There are a large range of types of questionnaire items, including, for instance: dichotomous questions; multiple-choice questions; rating scales; and open-ended questions (Wilson, 1996).

The researcher adopted multiple-choice questions, rating scales, and open-ended questions for the present study. The considerations for adopting these three were: multiple-choice questions and rating scales are quick to complete and straightforward to code. Open-ended questions enable the respondents to reply freely and reduce the restrictions of pre-set categories of response.

Tests

In addition to the items mentioned above, tests are an effective data collection technique and are an essential part of the experimental method of research. When constructing a test, some points need to be considered:

- (1) the purposes of the test, e.g. identifying the initial or entry abilities in a student or evaluating the student learning outcomes;
- (2) the objectives of the test, e.g. which student learning outcomes or content areas will be addressed;
- (3) the construction of the test, involving item analysis in order to clarify item discrimination and item difficulty;
- (4) the format of the test, e.g. layout, instructions; and,

(5) the validity and reliability of the test (Cohen et al., 2000).

Ary et al. (2002) suggest research workers construct their own test because a researcher-made test can be tailored to the specific research question. Standardized tests are generally designed to measure broad objectives and may not focus on specific skills the researcher wishes to measure. Therefore, the researcher constructed two tests conducting one before and one after the intervention to specifically compare the student test achievement in traditional and interactive teaching. The questions of both tests were different but tested the same content. Both tests were the same for the control and experimental groups. In this study, the Pre and Post-test were constructed for the traditional and intervention groups.

4.3 Research stages

The interval of data collecting can be sorted into three stages: Phase 1, Phase 2 and Phase 3. The sample subjects are Grade 11 and 12 students in Phase 1 and Grade 12 students in Phases 2 and 3. The timing, focus, and data collection methods are set out in Table 4.1 below.

Time	Focus	Data collection methods
<i>Phase 1: Understanding student and teacher views</i>		
1999 Sep	Student views of learning	Student Interview 1
Nov	Student views of learning in lecture classes	Questionnaire 1A
	Student views of learning in experiment classes	Questionnaire 1B
Dec	Student views of learning in lecture and experimental classes	Teacher Interview
<i>Phase 2: Conducting the intervention</i>		
2001 Aug	Student test achievement pre-intervention	Pre-test
	Student beliefs about the nature of science pre-intervention	Tsai's Pomeroy Questionnaire
	Student confidence about doing investigations	Confidence Questionnaire
Sep- Oct	Implementing the intervention	Assignments, work sheets & classroom observation
<i>Phase 3: Evaluating the intervention programme</i>		
Oct	Student test achievement post-intervention	Post-test
	Student beliefs about the nature of science post-intervention	Tsai's Pomeroy Questionnaire
	Student confidence post the conduct of open investigations	Confidence Questionnaire
	Student evaluating the intervention	Student Interview 2
	Student views of the traditional and interactive teaching	Questionnaire 2A1(traditional students), 2A2 (intervention students)
	Student views of the closed and open investigations	Questionnaire 2B1 (traditional students), 2B2 (intervention students)

Table 4.1: The timing, focus, and data collection methods in three phase

Phase 1: Investigating the existing situation

The focus of Phase 1 was to understand student and teacher perspectives of the traditional biology lecture and experiment classes in senior high school biology in Taiwan. Students were surveyed and interviewed and teachers were interviewed to

elicit their views. Table 4.2 summarises the participants and the data collection methods for this phase.

Participants	Data collection methods
49 Grade 11 students	Student Interview 1
523 students in total: <ul style="list-style-type: none"> ● 398 Grade 11 students ● 125 Grade 12 students 	Questionnaire 1A
485 students in total: <ul style="list-style-type: none"> ● 371 Grade 11 students ● 114 Grade 12 students 	Questionnaire 1B
12 teachers	Teacher Interview

Table 4.2: The participants and data collection methods in Phase 1

Forty-nine Grade 11 students were interviewed (Student Interview 1). Five hundred and twenty-three students (398 Grade 11 and 125 Grade 12 students) reported their views of the biology lecture classes in a questionnaire (Questionnaire1A). Four hundred and eighty-five students (371 Grade 11 and 114 Grade 12 students) were surveyed their views of the biology experiment classes in a questionnaire (Questionnaire1B). The same classes were surveyed for both questionnaires; however, around forty students were absent when the second questionnaire was conducted. It was winter and many students had the flu. These subjects were a mixture of boys and girls. Twelve senior high school biology teachers from eight schools were interviewed (Teacher Interview). They explained their concerns about student learning and their teaching in biology classes.

Phase 2: Conducting the intervention

Based on an analysis of the data collected in Phase 1, an intervention programme was created to further the Grade 12 student learning in biology. In the interactive teaching and open-ended investigation, student-student and student-teacher dialogues were audio-taped then transcribed as soon as possible. The transcripts revealed the student learning and the teacher teaching as a blend of questions and feedback, which was noticeably dissimilar from traditional biology classes. Because of the constraints of the tape recorder (a microphone must be close to

speaker); some of the dialogues were inaudible and could not be transcribed completely. The researcher tried to jot down the worthwhile dialogue and compared this with the transcripts to develop a more comprehensive image of what had taken place. In addition, the students were asked to complete one test, two questionnaires, assignments and work sheets. The Pre-test was conducted in the first biology class at the commencement of the new semester in 2001 August. A Chinese version of 20 items of Pomeroy's Questionnaire (a questionnaire designed by Pomeroy to examine scientists' and teacher beliefs about the nature of science) (Pomeroy, 1993) was adopted. This was provided by Dr. Chin-Chung Tsai (professor at Centre for Teacher Education, National Chiao Tung University, Taiwan) to examine the student beliefs about the nature of science. The Confidence Questionnaire, adopted from Haigh (1998), was designed to reveal the student declared confidence of doing investigation. In addition, the students were asked to do work sheets for each task in the biology laboratory and assignments for each lesson after school. The assignments were for enhancing the student ability in problem-solving, seeking and integrating information. Work sheets including planning and self-evaluation sheets were to support students in designing investigations and evaluating their performances. The students were required to complete a planning sheet at the beginning of each investigation but were allowed to hand in their self-evaluation sheets the next day. This written documentation was part of the assessment of student learning. During the class time, the students were observed and audio-recorded. Table 4.3 summarises the participants and data collection for this phase

Participants	Data collection methods
261 students	Pre-test
72 students	Tsai's Pomeroy Questionnaire
67 students	Confidence Questionnaire
73 students	Classroom observation, assignments& work sheets

Table 4.3: The participants and data collection methods in Phase 2

Phase 3: Evaluating the intervention

After the intervention programme, the researcher initiated an evaluation of the programme. Table 4.4 summarises the participants and data collection methods for this phase.

Participants	Data collection methods
280 students	Post-test
70 students	Tsai's Pomeroy Questionnaire
68 students	Confidence Questionnaire
23 students	Student Interview 2

Table 4.4: The participants and data collection methods in Phase 3

The Post-test was conducted to gain data for comparison with the outcomes of Pre-test, and was conducted in the first term examination in October 2001. The researcher administered both the Tsai's Pomeroy and the Confidence Questionnaire again after the intervention, to determine whether there were any changes in the student beliefs about the nature of science and their declared confidence, respectively. Twenty-three of the intervention class students were interviewed (Student Interview 2). They elaborated on their perceptions of the intervention. One hundred and ninety-five traditional class students filled out the questionnaires Q2A1 and Q2B1 to disclose their thoughts about the lecture classes and experiment classes. Seventy intervention class students filled out Q2A2 and Q2B2 to reveal their perceptions of the interactive teaching and open investigations. The researcher compared the traditional and intervention biology classes based on the data from student interview, tests and questionnaires.

4.4 Participants and data collection techniques

This section introduces the background of the participants in this study and the data collection techniques employed in this study.

4.4.1 The participants

There were three schools (A, B and C) of students involved in the survey in Phase 1. Schools A and B are co-ed. They have middle-band academic stream students. School C is a girls' school and is ranked the top senior high school in Taiwan. The

schools were selected based on convenience. The researcher knew the principals of these schools, could access the schools and was given informed consent to conduct the research at the schools. There were 340, 131 and 52 student participants from school A, B and C, respectively. The researcher teaches at school A. Only the students of School A were involved in Phases 2 and 3.

In Phase 1, the student participants were eleventh and twelfth graders (aged 17 and 18) destined for careers in science, medicine and technology. They were required to take biology and assigned as the third group of students in University Entrance Examination (as outlined in Section 2.4). Forty-nine interviewees were selected at random from the third group classes evenly in School A. The researcher had not taught nor did she know any of the students who were interviewed. The desired sample size was 50 (26 girls; 24 boys), but one (boy) was absent. The researcher had no intention to explore the gender effect. Students were selected at random. The number of participants who responded to the questionnaire on their views of the biology lectures and experiment classes was 523 (241 girls; 282 boys) and 485 (222 girls; 263 boys) respectively, including both 11th and 12th graders. They were students from Schools A, B and C. The participants and their gender see Table 4.5.

Participants	Gender
49 Grade 11 students	26 girls, 23 boys
523 Grade 11 and 12 students	241 girls, 282 boys
485 Grade 11 and 12 students	222 girls, 263 boys
23 Grade 12 students	6 girls, 17 boys

Table 4.5: The participants in Phase 3

The 12 interviewed teachers were distributed in 8 different senior high schools in the centre and north of Taiwan. They are the researcher's colleagues (5 teachers), classmates from graduate school or recruited by recommendation (7 teachers). Most of them lived in the northern area of Taiwan, which was near the researcher's residence except one teacher (T11), so it was convenient for the researcher to contact them. Their code, genders, school rank, school location, teaching years, and interview mode are summarized in Table 4.6 below.

Code	Gender	Rank of school (in that city or county)	Relationship	Teaching year(s)	Interview approach
T1	F	<i>M</i> (Taipei)	Colleague	25	f
T2	M	<i>M</i> (Taipei)	Colleague	2	f
T3	F	<i>M</i> (Taipei)	Colleague	24	f
T4	M	<i>M</i> (Taipei)	Colleague	18	f
T5	F	<i>M</i> (Taipei)	Recommendation	23	f
T6	F	<i>T</i> (Taipei)	Recommendation	6	f
T7	F	<i>M</i> (Taipei)	Colleague	1	f
T8	M	<i>T</i> (Hsinchu county)	Classmate	6	t
T9	F	<i>L</i> (Taipei)	Recommendation	16	t
T10	F	<i>L</i> (Taoyuan)	Classmate	8	t
T11	F	<i>T</i> (Chanhua county)	Classmate	6	t
T12	F	<i>T</i> (Taipei)	Classmate	6	t

Table 4.6: The details of the interview teachers

Key: (1) Gender: F-female, M-male

(2) Rank: ‘*T*’ represents top level (in this study, T6 teaches in the top girls’ high in Taipei, T12 teaches in the top boys’ high in Taipei), ‘*M*’ represents middle level and ‘*L*’ represents low level.

(3) Interview approach: f-face to face interview, t-telephone interview

In Phase 2 and 3, the researcher was also the teacher who taught two intervention classes and three traditional classes in the intervention programme. Another traditional class was taught by the researcher’s colleague. The intervention programme was a five-week cell biology unit, containing 14 lecture periods over 8 lessons and 6 laboratory periods for 3 tasks, a total of 20 hours teaching. All the laboratory exercises followed, rather than preceded, concept introduction and lectures. Two classes of twelfth graders (6 girls; 67 boys, total 73) received the intervention, and four classes (106 girls; 89 boys, total 195) served as control groups for quantitative analyses. In addition, interactions in the classroom were profiled qualitatively. There were 23 students who were interviewed, 2 girls and 21 boys. All the interviews and lessons dialogues were conducted in Mandarin

Chinese, audio-recorded, transcribed verbatim and simultaneously translated into English by the researcher. The questionnaires and documentation materials were likewise conducted in Mandarin Chinese and then translated into English. The researcher's supervisors checked the face validity of the English version of the questionnaire. The Chinese translation was checked by a science educator who was also a biologist and fluent in both English and Chinese

4.4.2 The techniques

The research techniques and instruments employed for the present study were interviews, classroom observation and written documentation. These are described below.

Interviews

The interview sequence, interview type, interview duration and timing are detailed in Table 4.7.

Interview sequence	Student Interview 1 (SI 1) (Pre-intervention)	Teacher Interview (TI)	Student Interview 2 (SI 2) (Post-intervention)
Type	Individual	Individual	Individual, group (in pair or triple)
Duration	20-40 mins	35-100 mins	50-120 mins
Date	Sep 1999	Dec 1999	Oct 2001
Time	Class (school) assembly, individual study	Available time in school	Lunch break (followed by class assembly)

Table 4.7: Illustration of interview sequence, interview type, interview duration and conducting time

Two different interview approaches in TI included seven teachers by face-to-face interviews and five teachers by telephone interviews. The teachers decided the interview approaches they preferred to use and were interviewed when they were available in school. The duration of the interviews was 20-40 minutes for SI 1, 35-100 minutes for TI, and 50-120 minutes for SI 2. The researcher used individual interviews in TI and SI1, but employed both individual and group interviews in SI

2. The students were interviewed during class, school assembly, or during individual study class time (SI 1), and lunch break following class assembly (SI 2). The reason for adopting individual interview in SI 1 can be attributed largely to the lack of familiarity between the researcher and the interviewees. In order to develop a trusting environment, the researcher would chat with the interviewee at the beginning of interview. A private setting was more suitable for that conversation because the interviewees may feel secure there. In SI 1, although some timid students displayed limited opinions as they were unfamiliar with the researcher, the large size of interview sample (49 students) compensated for the deficiency. At the end of each student interview, the interviewee was required to inform the next interviewee, and then go back to class. Interestingly, sometime the interviewee would accompany the next interviewee back again and show a fairly strong desire to continue the conversation. Under this situation, he/she was welcome to join in.

Student Interview 1 (SI 1) aimed to elicit the student responses about learning biology. There were 14 interview questions, which were arranged from general to specific. The interview attempted to gather baseline information about the student perceptions of learning biology in the lecture and experiment classes. Questions concerned with the lecture classes, perceptions as to why they take biology; what difficulties they have in learning biology; what approaches they use, prefer and feel helpful in learning biology; what ways they think would increase their biology marks; how they learn biology outside school; what they think about biology; and what changes they would like to see in the biology lecture classes. With respect to the experiment classes, student views were sought of doing experiments including the purpose, the learning, the unfit outcomes, the usefulness, and the changes they would like to see in the biology experiment classes. Table 4.8 shows the main points of SI 1. For the interview questions see Appendix 2.

Student interview 1	
Lecture classes	Experiment classes
1. Reasons for taking biology. 2. Obstacles to learning biology. 3. Preferred and most helpful ways of learning biology. 4. Learning biology outside school. 5. Thoughts about the biology lecture classes. 6. Changes they would like to see in the lecture classes.	7. The purpose of doing experiments. 8. Perceptions of doing experiments. 9. Learning from doing experiments. 10. Knowing what one is doing in an experiment. 11. Perceptions of unexpected experiment outcomes. 12. Perceptions of usefulness of doing experiments. 13. Comments of current experiment classes. 14. Changes they would like to see in the experiment classes.

Table 4.8: Main points of Student Interview 1

Teacher Interview (TI) sought to draw out what the teachers conceived to be student learning in both the lecture and experiment classes. Teachers were asked 15 questions. Some questions were same as SI 1, but some modifications were made, for example: replacing ‘What do you ...?’ to ‘What do you think students...?’ The main points of the other questions did not appear in student interview questions (see Table 4.9). For the questions of TI see Appendix 3.

Teacher Interview
<ol style="list-style-type: none"> 1. Reasons students should learn biology. 2. Attitudes students have toward the lecture and experiment classes. 3. Approaches of teaching biology and helpful to student learning. 4. Difficulties to teaching biology. 5. The degree of satisfaction with student learning outcomes and achievement in biology. 6. Views about interactive teaching and open investigation.

Table 4.9: Main points of Teacher Interview

Student interview 2 (SI 2) was conducted after the intervention to evaluate student learning outcomes in the interactive teaching. Similar questions were used in the student self-evaluation sheet for evaluating open investigations. There was no formal student interview about the open investigation, but some casual ones. The interview subjects were chosen based on the scores the students obtained (the calculation of score will be introduced later) in the Tsai's Pomeroy Questionnaire. The class was grouped into three groups based on student score in Tsai's Pomeroy Questionnaire. The first group was students with high scores, the second was students with middle scores and the third group was of students with low scores. Seven students were chosen from the high and low score groups, and six from the middle group. Three students volunteered, making the total number of interviewees 23. The intention of SI 2 was to identify student views about the interactive teaching, including the features, the learning outcomes, differences from previous lecture classes, and their suggestions and ideas about student and teacher responsibility in learning and teaching. For questions of SI 2, the key issues are shown in Table 4.10 (the questions of SI 2 see Appendix 4).

Student Interview 2	
1. Thoughts about interactive teaching. 2. Perceptions about the differences between the traditional lecture classes and interactive teaching. 3. Features of interactive teaching. 4. Perceived the type of learning gains the most in the interactive teaching.	5. Learning from the teacher's questions. 6. Learning from peer discussions. 7. Comments about the interactive teaching. 8. Suggestions of the interactive teaching improvement. 9. Thoughts about the student's and teacher's responsibility

Table 4.10: The key issues of the Student Interview 2

Classroom observation

In Phase 2, the researcher observed the students whilst she conducted the intervention. She kept observational head notes and audio-taped the classroom dialogues. Her status as participant-as-observer did not allow her to take field notes and hence she only jotted down very few key points during the teaching. Most data was written right after a lesson or task. In addition to direct observation, student informal interviews were undertaken as a part of the observational data. The dialogues recordings were transcribed as soon as possible after a lesson and the insights gained used to support of the remainder of the intervention the observations.

Written documentation

During all the three intervention phases, written documentation was collected through student questionnaires, assignments, work sheets and tests.

● **Student questionnaires**

A total of eight student questionnaires were administered in the research. These were: Q1A and Q1B for Phase 1; Tsai's Pomeroy Q and Confidence Q for Phase 2; and Tsai's Pomeroy Q, Confidence Q, Q2A1, Q2A2, Q2B1 and Q2B2 for Phase 3. The name and purpose of these questionnaires see Table 4.11 below.

Questionnaire name	Purpose
Q 1A	Student views of learning in lecture classes
Q 1B	Student views of learning in experiment classes
Tsai's Pomeroy Q	Students beliefs about the nature of science pre-intervention
Confidence Q	Students confidence about doing investigations
Q 2A1	Student views of the traditional teaching
Q 2A2	Student views of the interactive teaching
Q 2B1	Student views of the closed experiments
Q 2B2	Student views of the open investigations

Table: 4.11: The name and purpose of student questionnaire

The questions in the questionnaires Q1A, Q1B, Q2A1, Q2A2, Q2B1 and Q2B2 were arranged from general to specific to elicit the student responses. The purposes and focal points of all questionnaire conducted in this study are described as below.

The design of Questionnaire 1A (Q1 A) was in terms of the data analysis of the first interview (SI 1). For example, the responses from the interview question 'Why are you taking biology?' became the response items of the question in questionnaire 'I am taking biology for: a. increasing entry option; b. having strong interest in biology; c. related to my future career...' in which the students were asked to rank their top three reasons. In this way, the interview data could be supplemented by the questionnaire data. The interview and survey data triangulated each other in the interpretation of the results. The same principle also applied to Q1B, Q2A1, Q2A2, Q2B1 and Q2B2. In each question, there was an option 'others' to elicit the student open responses.

The purpose of the Q 1A was to understand student biology learning background and their perceptions of the biology lecture classes (see Appendix 5). Their motives for taking biology were required to help understand whether they take this subject for intrinsic factors, (for instance, interest in the subject) or extrinsic factors, (such as affected by others (*ibid*, Questions 1). In Appendix 5, Questions 2 reveal student biology learning background and satisfaction to biology learning.

Student perceived learning barriers were examined (*ibid*, Question 3). Student approaches of learning preferred, currently used, most helpful and those that might increase student marks were explored (*ibid*, Question 4). These generated information which helped with designing the intervention. The student beliefs about a good biology teacher and their attitudes toward biological question in daily life were also probed (*ibid*, Questions 7 and 5). At the end of the questionnaire, the student perception of their teacher's teaching approaches and comments about the biology lecture classes were sought (*ibid*, Questions 6 and 8). These were considered in the implementation of the interactive teaching as part of the intervention programme.

Questionnaire 1B (Q 1B) sought to elicit student perspectives of the biology experiment classes. In each question, except the ranking questions, there was an option 'others' to elicit open responses (see Appendix 6). In order to understand the student attitudes toward and views of doing experiments, their satisfaction with the biology experiment classes and the frequency of being an operator in an experiment, six questions were proposed (*ibid*, Questions 1 to 6.). To investigate the student perceptions about learning from doing experiments, two questions were posed (*ibid*, Question 7 (1) and (2)). With respect to student views of teacher's instruction and demonstration before doing experiments, their chance of being the operator and chatting with other students, and how they deal with discussion at the end of an experiment see Questions 8 to 10. The student perspectives regarding the type of the biology experiment classes they preferred and they actually engaged are dealt with in Question 11. For the question used to understand the student thoughts about making hypotheses, see Question 12. The student comments about the current biology experiment classes provided the researcher suggestions for the design of open investigation in intervention programme (*ibid*, Question 13).

Tsai's Pomeroy's Questionnaire was for examining student beliefs about the nature of science. Tsai (1996) selected 20 items from Pomeroy's Questionnaire (Pomeroy, 1993) and translated them into Chinese. Tsai's Pomeroy Questionnaire consists of bipolar agree-disagree statements on a Likert scale, they reflect objectivist to constructivist views about science. For the constructivist perspective

items, a ‘strongly agree’ response was assigned a score of 5 and a ‘strongly disagree’ response was assigned a score of 1. Items representing an objectivist view were scored in a reverse manner. Thus, students having strong beliefs about constructivist views would have higher average scores. For the English and Chinese versions of Tsai’s Pomeroy Questionnaire see Appendix 7.

Confidence Questionnaire (see Appendix 8) to elicit information on student confidence was adopted from Haigh (1998). She developed fourteen questions based on statements at Level 6 in the ‘Developing scientific skills and attitudes’ learning strand in the *Draft New Zealand Curriculum Statement in Science* (Ministry of Education of New Zealand, 1992). The questionnaire was administered both pre- and post-intervention to examine student confidence regarding fourteen aspects of investigation. These were to do with confidence in: making hypotheses; dealing with the investigation of more than one changing factor; identifying the sources of error; and so on. For the questions, ‘very confident’ was assigned a score of 4, ‘reasonably confident’ 3, ‘not very confident’ 2 and ‘not confident at all’ 1.

After the intervention, both traditional and intervention classes of students were asked their thoughts about their theory teaching classes. Q2A1 was for the traditional students and Q2A2 for the intervention students (see Appendices 9.1 and 9.2). These two questionnaires consisted of bipolar agree-disagree statements on a Likert scale. Q2A1 and Q2A2 contained 23 and 28 close-ended questions, respectively. The students were asked to respond to questions about the teacher, teaching, learning and overall evaluation. The 23 closed-ended questions were same for the two questionnaires. In addition, the intervention students were asked other 5 closed-ended questions and there was an open question ‘Is interactive teaching feasible? Why?’ at the end of Q2A2.

As in Q2A, Q2B1 was for the traditional students and Q2B2 for the intervention students (see Appendices 10.1 and 10.2). These two questionnaires were developed to elicit student perceptions of their experiment classes in terms of cognitive aspects, process skills and affective aspects. Q2B1 and Q2B2 contained 24 and 25 closed questions, respectively. Q2B2 had an additional open-ended

question at the end of the questionnaire, which was: ‘Is open investigation feasible? Give reasons.’

- Other written documentation

The students, involved in the intervention programme, were asked to do assignments, work sheets and a written report while carrying out the open investigation and/or after school. This written documentation was collected. Work sheets, including a student planning sheet and self-evaluation sheet, were modified from Haigh (1998). There was no definite format of a student group report sheet.

Student planning sheets were used to help students to design their own task before doing open investigation. In the open investigation, the students were asked to design their own investigation. However, it became apparent they lacked the experience required to do this. To help the students, a couple of questions were provided to guide them in focusing on different aspects of the design of investigations. These were added to the original student task sheet. The questions listed on planning sheets of Task 1 are different from those on Tasks 2 and 3 due to the nature of the tasks. Task 1 is a microscope observation activity. Tasks 2 and 3 are fair-tests. The original student planning sheets include the task sheets and auxiliary questions (See Appendices 11.1, 11.2 and 11.3). The questions are shown on Figure 4.1.1 and 4.1.2. In Task 1, they were guided to consider the types and levels of living samples, and to think about processing the samples, what they need to record and draw, and the presentation of results (see Figure 4.1.1).

Student Planning Sheet – Task 1

1. What am I trying to do?
2. Is there any background knowledge I should consider? How can I find it?
3. What types of living thing I am going to take?
4. What level of living things (organ, tissue, cell....) could I observe under microscope? Why?
5. What factors do I need to think about?
6. How am I going to deal with the living things? What equipments do I need?
7. In terms of the features of the objects, what do I need to record and draw?
8. How am I going to present my results? Do I need to draw up a table?

Figure 4.1.1: Student planning sheet for Task 1.

In Tasks 2 and 3, the students were guided to consider different variables, ways of processing the samples, what measurements should be taken, ways of presenting data, and how to apply the outcomes to their daily life. These questions are shown in Figure 4.1.2.

Student Planning Sheet – Tasks 2 and 3

1. What am I trying to do?
2. Is there any background knowledge I should consider? How can I find it?
3. What is going to be the independent variable (i.e. the one I am going to manage)? What is the dependent variable (i.e. the one I am going to measure changing)? What variables have to stay constant (i.e. which ones am I going to control)?
4. How am I going to deal with the samples? What equipment do I need?
5. What sort of measurements (mass, volume, colour change...) will I need to do?
6. How often do I need to take the measurements? How many times should I repeat the experiment?
7. How am I going to present my results? Do I need to draw up a table or graph?
8. Give the examples where you could apply what you have learned from this investigation to daily life (only for Task 3).

Figure 4.1.2: Student planning sheet of task 2 and 3.

Student self-evaluation sheets were used to encourage students to evaluate their performance, interpret their outcomes, identify the imperfections, and express their feelings about carrying out the investigations (see Figure 4.2 and for the details see Appendix 12).

Student Self-Evaluating Sheet

1. Title of investigation.
2. How well do I think I carried out the practical work? (Proud of, should be improved)
3. When I was carrying out the practical work, what more would I like to know?
4. What do I think I have learned today?
5. What are my findings? Are they different from what I thought would happen? What have I found that I did not know before? How can they be explained?
6. What do you think the sources of error come from? How can you be sure?
7. Do you have any questions about things you didn't understand yet?
8. What are the differences between this investigation and the previous one?
9. What do you like and dislike about this investigation? Why?
10. Suggestions for improvement of the investigation.

Figure 4.2: Student self-evaluation sheet

In accordance with the lecture class, the students were asked to complete one question related to each lesson after school to evaluate whether they understood the teaching content and appreciated how to apply this in their daily life. These questions focused on problem-solving, information searching, analysing and integrating ideas (See Appendix 13).

Pre- and Post-test, designed by the researcher for the six classes, attempted to measure what the students had learned about cell biology. They were conducted before and after the intervention programme in the lecture classes. There were 25 items of multiple-choice and only one right answer in each item in both Pre- and Post-test (see Appendix 14). The outcomes of the tests were employed as auxiliary tools in evaluating the influences of the intervention programme on student achievements. The research had no intention to identify the effect of the intervention exclusively by the achievement tests, they were used to triangulate with the other research methods.

4.5 Data analysis

Data analysis involves finding patterns in data and developing ideas that help explain why those patterns are there in the first place (Bernard, 2000). Through a process of analysis data is transformed into findings. Data analysis is a highly challenging task and also time consuming, especially in qualitative analysis. The challenge is in making sense of massive amount of data, reducing the volume of information, identifying significant patterns and constructing a framework for communicating the essence of what the data reveal (Patton, 2002). There are no commonly agreed-upon procedures for this task (Best & Kahn, 1998). In this study, the purpose of data analysis was to identify, from the participants' point of view, the existing learning situation in biology and how the intervention influenced student biology learning. Different data sources, such as interviews and written documentation and so on, were compared.

4.5.1 Basis of analysis

The methods for qualitative and quantitative data analysis were different. In qualitative analysis, raw data were categorised and reorganised to identify themes, and then interpretation was employed to search for meaning (Patton, 2002). In this study, all the tapes of interview and class dialogues were transcribed in Mandarin and then translated to English. The interview and lesson transcripts were used to categorise responses. Broad categories of student and teacher responses were discerned first, and more fine-grained distinctions were made upon repeated reading. Once organising themes had emerged from the qualitative data, the interpretation was the final and most critical phase of the analysis process (Bernard, 2000; Berg, 1995; Best & Kahn, 1998). Through interpreting the data, coherent answers to major descriptive questions are put together. In this way, readers can comprehend where the conclusions come from and agree or disagree with them. Appropriate interpretation is able to capture the authentic meanings behind the themes (Altheide & Johnson, 1994; Huberman & Miles, 1994; Richards & Richards, 1994). Interpretations attach significance to particular outcomes and put patterns into an analytic framework (Patton, 2002). The data collected on classroom discourses were interpreted to describe, for example, the effects of the intervention on student learning. The other qualitative data such as

student work sheets and written reports were important sources of data in the open investigations, which revealed the students engaged in thinking processes and how they constructed meaning from dynamic classroom practices.

The quantitative analysis techniques used in this study are univariate analysis and bivariate analysis. Univariate analysis analyses a single variable at a specific time. The raw data coming from student questionnaires was transformed into a set of frequency distributions and/or displayed through bar or pie chart, which belonging to the criterion of univariate analysis. Frequency distributions provide hints about how to collapse variables (Bernard, 2000). The numbers of occurrence and percentages represent a measurement of responses. In bar chart, each bar represents the percentage of response falling in each category. Pie charts show the relative size of the different categories and the size of each slice relative to the total sample (Bryman, 2001). These techniques were used for both the quantitative interview data and the questionnaires Q1A and Q1B. Bivariate analysis investigates relations between pairs of variables. For non-parametric data, Wilcoxon test for ordinal (ranked in order) data within groups was used in Tsai's Pomeroy Questionnaire due to the same group being tested at different times, and Mann-Whitney U test for ordinal data between groups was used in Q2A1, Q2A2, Q2B1, and Q2B2. As for parametric data, a two-sample t-test was employed to evaluate whether the means of two independent groups differ on some variables. In this research, the paired t-test was adopted for Pre- and Post-test and Confidence Questionnaires due to the same group being tested at different times. The software used for processing quantitative data in the present study was SPSS software package Window Chinese vision 8.0.1.

4.5.2 Coding system employed

In Phase 1, interview data were coded. A letter and a number follow every quotation, F for female, and M for male. A number then represents the order the student was interviewed, e.g. F1 meant the first female student the researcher had interviewed in year 1999. A similar strategy was used for coding teacher interviews. The twelve interviewed teachers were allocated codes T1 to T12.

In Phases 2 and 3, the coding principle changed slightly. In the classroom transcripts and student interviews, S was used for students followed by a number to represent the room number and student seat number, e.g. S2301 meant the intervention student the researcher interviewed in year 2001 who belonged to Room 23 and had seat number 01.

4.6 Overall considerations

During the research stage, there was a need to consider whether the data collected had congruent validity and whether the participants' rights were protected. This section discusses validity and research ethics.

4.6.1 Validity

To enhance internal validity, Guba and Lincoln (1989) suggest a number of techniques. The techniques relevant to this study are: prolonged engagement, persistent observation and peer debriefing. Firstly, the researcher with an intention to avoid the possibilities of misinformation and distortion spent a year with the Phase 2 participants to build the rapport and trust necessary for the implementation of an innovation that would challenge student expectations of teacher and student roles. Secondly, the researcher observed the participants for a long time to identify important characters and elements in their context that are relevant to the issue being pursued. Lastly, during the process, the researcher frequently discussed with a disinterested peer the data she was collecting and her analysis and conclusion form the data. This helped the researcher reflect on and better understand her own stance, values and role within the study, both as the teacher of the innovation and as the researcher of the innovation.

To enhance external validity of the study and findings, the researcher has provided considerable details about the participants, the context and the research process. In this study it is hoped that the reader will have sufficient information to make decisions about whether the findings of this case study of the use of more open investigation could be applied to their own situation.

To further add to the validity of the study triangulation of data was employed. Triangulation is a powerful way of demonstrating congruent validity especially in

qualitative research (Best & Kahn, 1998; Cohen et al., 2000; Neuman, 2000). It may be defined as using two or more data collection methods to generate conformation on human behaviour from different standpoints. In interpretive research, triangulation is used to investigate human behaviour by making use of both qualitative and quantitative data. Employing a multi-method approach minimises the impact of a researcher's predispositions (Cohen et al.) The deficiencies of one method are addressed by the advantages of another (Best & Kahn, 1998). With triangulation, the researcher can have greater confidence in data generation. Meanwhile, the researcher's critical self-reflexivity was used. In this research, qualitative data sources were the interviews, classroom observations, open-ended items in the questionnaires and other written documentation, e.g. student evaluation sheets. These were compared to and supplemented by quantitative data from closed items in the questionnaires, Tsai's Pomeroy Questionnaire, Confidence Questionnaire and the Pre- and Post-test. The researcher employed methods triangulation (such as interview, questionnaire and documentation) and data triangulation (gathering data at different times and in different places and using different subjects) to increase the validity and reliability of this research.

For methods triangulation, for example, the items of questionnaire Q1A and Q1B were designed based on the outcomes of interview SI 1. Therefore the outcomes of Q1A and Q1B could be compared with the outcomes of SI 1; or the outcomes of student evaluation sheet were compared with the questionnaire Q2B2 and reliability was identified.

Data was triangulated over time, place and subject through the comparison of data from three schools of over 500 students in 1999 and data from one school of about 280 participants in 2001.

4.6.2 Research ethics

The public has the right to know and the individual has the right of privacy (Pring, 1984), which becomes a researcher's dilemma. For ethical reasons and in an attempt to seek a balance between the researcher and research participants; there

are three considerations to keep research going and protect participants; informed consent, anonymity and confidentiality.

Recruitment of volunteers for an experiment should always involve their completely understanding the procedure used, the potential risks and the demands that might be made on the context in the study. Participants should be informed of the purpose of the research. Being aware of this, the researcher sought consents from the principals, teachers and students of three senior high schools before the commencement of the research. The principal of the school in which the researcher intended to have intervention gave his written consent, and the other two principals gave verbal consent for this study. All the participating teachers and students were given a written summary of the purpose of the study and their right to withdraw and to confidentiality. Participants knew they were being tape-recorded and they had the right to withdraw during the period of research time if they felt uncomfortable. When the respondents filled out the questionnaire, there was no need for them to write down their names except that the 73 participants who were in the treatment group of the intervention programme were asked to write down their seat number in the Tsai's Pomeroy Questionnaire and Confidence Questionnaire. The 73 participants were asked to write down their seat number because the researcher attempted to investigate the interplay between their scientific epistemological views and their confidence change after intervention. Before the commencement of the research, the researcher had given an explanation to the respondents and they agreed with this. Only the researcher knew who provided the information. A coding system was used to ensure complete anonymity and confidentiality. The researcher was aware that guarantee of confidentiality was her obligation and all promises must be taken seriously.

4.7 Summary of research methodology

This research is within an interpretive framework and intends to understand the nature of the research subjects and their behaviours. Both qualitative and quantitative methods were employed to scrutinise the different aspects of the research question. There were three research stages. In Phase 1, student and teacher views of the senior high school biology classes were explored. Based on the outcomes of Phase 1, an intervention was devised in Phase 2. The intervention

was evaluated in Phase 3. The techniques adopted in this research project include interviews and written documentation. Qualitative and quantitative data have been analysed and interpreted by different analysis techniques. The validity of data and research ethics have been seriously considered.

Within an interpretive framework, both the students and teachers perceptions of the student existing learning situations in biology classes are set out in Chapters 5 and 6.

Chapter 5

The student perceptions of biology learning and teaching

5.1 Introduction

In this chapter, the senior high school student perceptions of the biology lecture and experiment classes are discussed and a mix of qualitative and quantitative data is reported on. Qualitative data was collected by means of 49 interviews with a subset of the survey students who were selected at random from the third group classes evenly in School A (the interview questions, see Appendix 2: SI 1). These results were used to generate two questionnaires (Q1A and Q1B, see Appendices 5 and 6) which were then administered to the whole student group to obtain quantitative data.

The student reasons for taking biology are explored in Section 5.2. The learning approaches to biology, which the students preferred, currently used, perceived most helpful, and deemed most able to earn marks, are examined in Section 5.3. The student thoughts about learning in the lecture classes are outlined in Section 5.4. The changes the students would like to see in the biology lecture classes are discussed in Section 5.5. Their thoughts about learning in the experiment classes are presented in Section 5.6 and the changes they would like to see in the experiment classes are discussed in Section 5.7. Section 5.8 provides a summary of this chapter.

5.2 Student reasons for taking biology

Student purposes and motivations affect the approaches they use to interact with learning materials. To discover students' actual reasons for taking biology is (the questions see Question 1 in Appendices 2 and 5), therefore, a part of this study.

Eight categories of reasons were found for taking biology (see Table 5.1). These are presented in decreasing order of response in interview data. The same details

are shown for the questionnaire data. The students were allowed to offer only one reason in both the interview and questionnaire.

Why are you taking biology?	Percentage %	
	Interview data (N=49)	Questionnaire data (N=523)
For increasing entry options to university	24	21
For interest	20	18
For understanding of one's existing environment	16	16
For perceived ease of learning	16	9
For a future career	10	16
Affected by someone	6	6
As a prerequisite for a university course	4	7
For an outcome on an aptitude test	2	3
Other	2	4

Table 5.1: Student reasons for taking biology arising from interview and survey

The outcomes of interviews and questionnaires in Phase 1 indicated that the overall trend of the responses from the two data sources were similar, except for *perceived ease of learning biology* and its relevance *for a future career*. *Increasing entry options to university* was the major reason for students taking biology, and then interest. Twenty-four percent of the interview students and 21% of the survey students indicated they were taking biology to increase their entry options to university. In an effort to gain entry to university, students might take biology at the expense of other interests. One explained:

I take biology, so I can span different groups. In fact, I am not interested in biology at all (M17).

Twenty percent of the interview students and 18% of survey participants said that they were taking biology for *interest*. The interview students explained their interest arose from living in a natural habitat, watching TV or video biological programmes, parents buying books or subscribing to magazines relevant to biology and being affected by families or relatives whose jobs are related to biology. Some of them felt biology was the most interesting subject of all. Others

noted that biology is not easy but it is interesting. Some stated their interest in learning biology. For example:

Biology content is very interesting and inclusive. Even if the lecture is boring, I still like it (F15).

Sixteen percent of the interview and survey students took biology because they wanted to *understand their existing environment*, which was closely related to their daily life. Sixteen percent of interview and 9% of survey students took biology for *perceived ease of learning*. Ten percent of interview and 16% of survey participants thought taking biology would be helpful for them *in the pursuit of better jobs in the future*. The other reasons *influenced by someone, as a prerequisite for a university course, for an outcome of an aptitude test* and others were listed by fewer than seven percent of participants.

In short, the main reason for the students taking biology was for increasing entry options to university. While students gave eight reasons for taking biology, six of the cited reasons related to extrinsic factors and three of the six were future oriented.

5.3 Student perceptions of different approaches to learning biology

A broad picture of student learning approaches was generated by interviewing 49 students. Based on the outcomes of the interviews, a questionnaire was designed to obtain more quantitative details about the relationship between the student approaches that students currently used, preferred, most helpful and most useful for increase marks.

5.3.1 Student approaches to learning biology

The interview students indicated that there were many approaches to learning biology (For the question see Appendix 2 Question 3). These responses are grouped into eight categories and are presented in decreasing order in Table 5.2.1. The students often listed more than one learning approach. The percentage reflects the proportion of the 49 students who cited each approach.

Preferred or considered most helpful approaches of learning biology	Percentage (%) (N=49)
Watching videos or TV	59
Peer discussion	39
Reading	37
Outdoor activities	31
Teacher's lecture	27
Press and media	22
Rearing or growing living things	18
Seeking information	18
Attending biology club	12
Consulting people	12
Living in a natural habitat	10
Practising with supplementary exercises	8
Teaching aids	8
The process of solving problems	4
Imagination	2

Table 5.2.1: Summary of approaches that the students preferred to use or considered most helpful in learning biology

Watching TV and reading

From the interview students declared they preferred to learn biology through watching TV (59%) programmes or videotapes and extensive reading (37%). Some students admitted watching TV is relaxing and easy for them to understand. They did not have the habit of reading and their difficulty in comprehension led to their being not interested in reading. In contrast, other students said they not only enjoyed reading biology relevant publications but also perceived reading led to greater retention of knowledge than watching TV. Two explained:

Science books or magazines have too many words. I have no patience to read word by word. Hence, I didn't read so often as watching TV as it is faster. Sometimes, the content of biology relevant books describes too much and it is not easy to understand (M6).

I forgot what there was after turning off TV, but I can recall knowledge by reading (F8).

Here these two approaches have been collapsed because students quite often made comparisons between them suggesting they served as alternative source of information.

Peer discussion

Students affirmed peer discussion, in and out of class, was most helpful in learning biology (39%). In the process of student discussion, even if the students were not experts, peers' explanations were sometimes easier to understand and more acceptable than a teacher's interpretation. They were not afraid of asking peers questions. As two commented:

I prefer to discuss with my classmates. Although they are not as well-informed as a teacher, we are more easily to accept their explanations. Sometimes, the discussions are even more helpful than teacher's words (M4).

Students are not afraid of asking easy questions of other students but feel embarrassed to ask a teacher (F26).

Three students disagreed with having peer discussion in class. They said that it was most likely to lead to disorder or to be inconclusive. For example:

Students discussing in class might lead to chatting or not reach any conclusions due to too many opinions (M23).

Out of class activities

About one third of the students considered museum visiting and field trips as helpful learning approaches which could activate their interest toward biology and were helpful (31%). They perceived that these ways provided them with opportunities for learning in a natural setting different from the traditional classroom. By doing these activities they also had the chance to learn from others. For example:

Visiting a tea farm helped me to know where the tea trees grew and how to make tea. The farmer taught me much about his own experiences (M5).

Teacher lectures

That teacher lectures played an important role in student learning in biology was reported by students (27%). They placed the responsibility for their learning on the teacher. It was the teacher's role to transmit knowledge to students and the students supposed they could absorb it. As two said:

If the teacher provides more information and teaches in a more lively way, we will learn better (F3).

I rely on the teacher's notes on the blackboard. I am lazy about reading. I hope the teacher will prepare everything and the only thing I need to do is just receive it (F20).

These views of teacher and student roles in student learning are consistent with the behaviourist views of learning.

Attending Biology Club

Students emphasized the advantages of attending the school's Biology Club (12%). Biology Club provided them opportunities for field trips, from which they learned a lot. Also, an apprenticeship system existed in the Club. The senior students helped the junior ones and created opportunities for them to identify living things. One student even sacrificed his schoolwork to attend the club, and did not regret this, as he described:

Attending Biology Club is most helpful to me. I have attended many biology-related activities, which is why I failed twice – I studied in Grade 10 for three years. I don't regret spending another two years in Grade 10. I have enjoyed learning from those activities over the years (M18).

Practicing with supplementary exercises

A few of students believed that commercial drill and practice oriented work sheets, although no fun, were undoubtedly of value (8%). For example:

Although writing supplementary exercises repetitively is very boring, it is very helpful (F20).

The other learning approaches included learning common sense from the newspaper and radio, raising animals or growing plants, seeking information from the library or via the Internet, consulting people, living in a natural habitat and others showed a low percentage.

5.3.2 A comparison of student perceptions of learning approaches

To find out more about what approaches the students currently used, preferred, felt most helpful, and considered most useful for increasing marks, students were asked for these in the survey (see and Appendix 5 Question 4). Their responses

are summarized in Table 5.2.2 below. The students were allowed to tick more than one item.

Learning approaches	Now using (%)	Prefer to use(%)	Most helpful (%)	Increasing marks (%)
Carrying out school experiments	65	69	42	35
Peer discussion (in or out of class)	45	46	28	47
Participate in a teacher-led discussion	21	31	22	33
Visiting activities	<i>12</i>	74	42	<i>8</i>
Attending biology relevant clubs or activities	<i>9</i>	49	34	<i>8</i>
Field trips	<i>8</i>	70	42	<i>9</i>
Listening to a good lecture	48	70	49	67
Reading the textbook	82	<i>15</i>	<i>18</i>	76
Copying summaries from the blackboard	65	<i>18</i>	<i>13</i>	74
Using test books and practising repeatedly	62	<i>9</i>	<i>9</i>	78
Learning from press media	31	64	43	10
Reading science books or magazines	28	67	54	13
Watching videos or TV science programmes	35	72	55	13
Teaching aids	17	47	21	17
Raising a pet or growing plants	<i>13</i>	54	32	<i>5</i>
Going out with families or friends	<i>13</i>	51	21	<i>5</i>
Country life observation	<i>9</i>	53	34	<i>6</i>
Accessing the Internet	<i>12</i>	<i>27</i>	<i>16</i>	<i>6</i>
Learning from the process of solving problems	18	42	28	25

Table 5.2.2: Summary of the learning approaches that the students were using, preferred to use, considered most helpful and perceived could increase marks in learning biology (N=523)

Key: (1) **Bold:** represents most prevalent responses (based on rank)

(2) *Italic:* represents least prevalent responses (based on rank)

The data showed that students were using four main approaches to learn biology; *reading the textbook* (82%), *carrying out experiments in the school laboratory* (65%), *copying summaries from the blackboard* (65%), and *using test books and practising repeatedly* (62%). Less than 15% of the students used the following ways; *raising a pet or growing plants* (13%), *going out with families or friends* (13%), *visiting activities* (12%), *accessing the Internet* (12%), *attending biology relevant clubs or activities* (9%), *country life observation* (9%) and *field trips* (8%).

The seven ways the students preferred to use for learning biology were; *visiting activities* (74%), *watching videos or TV science programmes* (72%), *field trips* (70%), *listening to a good lecture* (70%), *carrying out experiments in the school laboratory* (69%), *reading science books or magazines* (67%), and *learning from the press media* (64%). The ways ranked as the last four the students preferred to use were; *accessing the Internet* (27%), *copying summaries from the blackboard* (18%), *reading the textbook* (15%), and *using test books and practising repeatedly* (9%).

The overall trend in student helpful approaches was very similar to their preferred approaches. The ranks of the top seven and the last four ways of the two questions were the same, although the percentages were less for each as a most helpful approach (between 55 and 42% rather than 74 and 64%). Less than 20% considered *reading the textbook*, *copying summaries from the blackboard*, *using test books and practising repeatedly*, and *accessing the Internet* to be the most helpful ways of learning biology.

Also, the overall trend in student approaches to increase marks was very similar to that in approaches they were using except for *carrying out experiment in school laboratory* and *listening to a good lecture* (see Table 5.2.2). Over 67% of the students perceived that *listening to a good lecture*, *reading the textbook*, *copying summaries from the blackboard* and *using test books and practising repeatedly* could increase their marks. Less than 10% perceived *visits*, *attending biology relevant clubs or activities*, *field trips*, *raising a pet or growing plants*, *going out*

with families or friends, country life observation and accessing the Internet would help in increasing their marks.

Of the key components of traditional biology lessons, approximately two thirds of students preferred to use and were using *carrying out experiments in school laboratory* to learn biology. They considered this was helpful. Nevertheless, they did not suppose this had much benefit in increasing their marks (see Table 5.2.2). This set of responses suggested that, in their minds, students did not consider the helpful ways of learning as necessarily being related to examination marks. *Peer discussion*, ranking high in the options ‘now using’ and ‘increasing mark’, was highly praised in student interviews (see Table 5.2.1). Seventy percent of students preferred to use the approach *listening to a good lecture* and confirmed it was relatively helpful and could increase marks. However, the percentage who said they were actually using this was ranked middle. Additionally, *visiting activities, field trips, learning from press media, reading science books or magazines and watching videos or TV science programmes* were approaches many students considered most helpful but in each case 8-35% students identified these as ways they were using and 8-13% thought they benefited in increasing marks. *Raising a pet or growing plants, going out with families or friends, country life observation* were ways half of the students preferred to learn biology. However, they seldom did this and thought it of little help to increase their marks. Most students frequently *read the textbook, copied summaries from the blackboard, used test books, and practised exercises repeatedly*. They supposed these approaches could increase examination marks efficiently. However, these ways were also the ways they most disliked and regarded as least helpful to learning. It seemed that in order to increase marks, they used approaches they much disliked.

5.3.3 Summary of student approaches to learning biology

To summarize, the learning approaches the students most preferred to use were also what they considered most helpful in learning biology; and the approaches they currently used were also what they thought of as being able to increase marks. However; evidence is provided that the approaches the students currently used were those they disliked and thought least helpful for their learning, but they perceived their benefit in increasing marks. The students rarely used those

approaches they preferred and perceived most helpful in biology learning and the approaches were perceived as being of little help in increasing marks.

5.4 Student thoughts about learning in the lecture classes

The student perceptions about the biology lecture classes, their views of learning difficulties, the relationship between student marks and their motivation toward learning, and other general comments were sought via interviews and/or questionnaires. These data are reported in this section.

5.4.1 Learning difficulties

Responses from the interviews indicated that during biology lectures the students considered they encountered obstacles which might impede their learning of biology. The students were asked what difficulties they had in learning biology (see Appendix 2, Question 2) and their responses are summarized in Table 5.3. Five categories of student difficulty are presented in decreasing order of reporting (Some students cited more than one difficulty).

Category	Percentage (%) (N=49)
Assessment favouring memorizing	43
Difficulties with the textbook	37
Do not support genuine understanding	35
Seeking for information	12
Others	12

Table 5.3: Student difficulties in learning from biology lectures

Assessment favouring memorizing

Students indicated that current assessment mechanisms did not encourage thinking. They proposed arguments for not using thinking and strategies for coping with tests and suggested assessment for learning (43%). They said their learning strategies were different in elementary school and high school because of the examination which required them to recite textbooks and remember the correct answers. A representative comment was:

In elementary school, I was interested in the surrounding environment and liked to explore it. However, this did not happen in senior high school because of the tests (F26).

Student F17 thought thinking would create more than one answer or submerge the correct one. Therefore, memorizing became her main learning strategy to earn marks. She explained:

Every question has a standard answer in tests. Thinking too much may disturb your writing down the 'right' answer. If your answer is unmatched to the standard one, it will not be accepted. Hence, memorizing knowledge is of more benefit to us (F17).

The current assessment encouraged rote learning. Students reported recall was helpful for preparing for tests, although they did that with little pleasure. As two stated:

Memorize all the knowledge in textbooks, and then there are no problems dealing with tests (M2).

Memorizing texts to cope with tests is painful (M19).

Although students did not like memorizing, they still employed this strategy because they placed a high value on earning marks thereby suggesting the influence of examination culture in Taiwan on student learning approaches. One commented:

I do not like it, but I need to practice test sheets quite often to cope with school tests (M17).

One student believed that effort rather than interest could increase his marks. In his words,

Good marks are the outcome of effort and irrelevant to interest (M16).

Student F15 suggested that teachers should adopt alternative assessment strategies, such as examining how they inferred, judged and made conclusions, instead of just demanding right answers. Also, she thought teachers should provide a chance for them to discuss their ideas. She suggested:

The teacher should consider the pupils' thinking process instead of just checking the final answer. During the assessment, the teacher could even discuss with us how to correct our concepts (F15).

Difficulties with the textbook

Too much content in the textbook and students having comprehension problems in reading textbook were complained of by the students and they suggested the textbook making changes (37%). One complained:

The content of textbook is too much and it is hard to understand (M4).

The other two students suggested textbooks needed to include more illustrations and make better links between abstract and concrete ideas. One said:

I feel the ideas are abstract because there are insufficient graphs and models in textbook (M21).

Do not support genuine understanding

In all, students asserted some biology concepts were abstract and not meaningful to them and had little linkage to their daily life (35%). They had difficulty in dealing with formal concepts, such as enzyme of cell biology, in a meaningful manner. For example:

Some objects and events are abstract to me, e.g. enzymes and their functions (F12).

Other students indicated that even when they successfully provided right answers to the teacher' questions they did not really understand the precise meaning of the answers they had given. One admitted:

I use the words in the textbook to reply to teacher questions, but actually I do not understand them (F15).

One student explained that even when she had learned the theories required to solve problems in the lecture classes, she continued using intuitive ideas to solve problems after classes. Apparently, she could not apply the theories taught due to finding them abstract and unrelated to their everyday life. In her words,

I don't use the principles of classification of plants and animals, which I have learned from the lecture classes to judge a creature, but make use of my intuition. The principles seem to be suitable only for specific laboratory situations (F8).

The others stated they required concrete objects, pictures, specimens or videotapes to promote their understanding; otherwise even with elaborate instruction they did not develop understanding. One said:

I have to recall much knowledge with which I am unfamiliar. I need to see concrete objects. Don't just tell me what starfish is. Show me (F9).

The categories *seeking for information* and *others* are not discussed because of the low percentage reported.

To conclude, the current assessment emphasized one right answer, which disengaged students from thinking and encouraged rote learning. Students had difficulties in understanding text because the textbook provided too many facts with little explanation where they came from. Students indicated that some biology concepts were abstract, irrelevant to daily life and did not support students developing genuine understanding.

5.4.2 The relationship between student marks and their motivation toward learning

Section 5.3 argues that under the pressure of University Entrance Examination (UEE), the student approaches of learning tended to be restricted to those helpful for passing examinations. Therefore, it would be interesting to find out to what extent they were interested in biology and whether marks influence their motivation toward learning biology (see Appendix 5, Question 2 (a) and (d)). Their responses are shown in Figure 5.1.

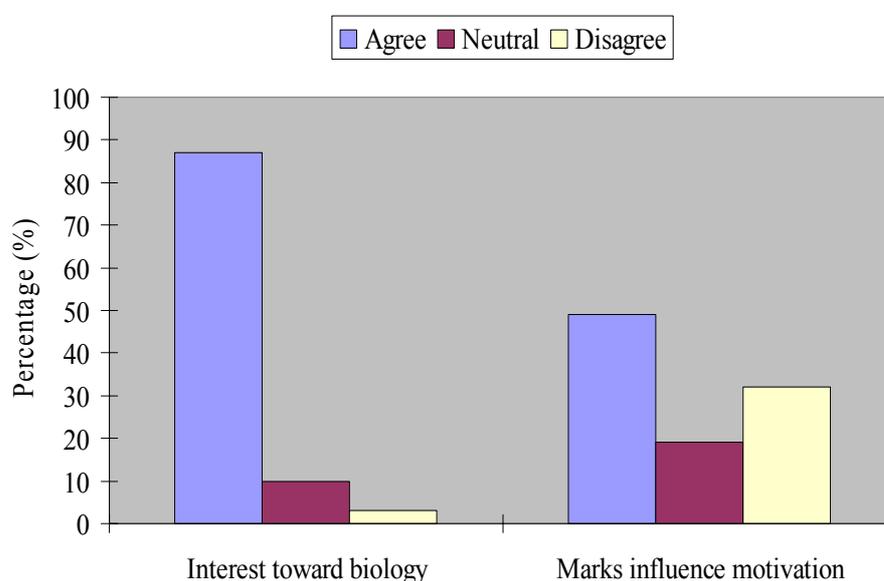


Figure 5.1: Student perceptions of interest and the influence of marks on motivation toward learning biology (N=523)

According to Figure 5.1, 87% of the students were interested in learning biology and almost half of the students (49%) admitted that their motivation toward learning biology was influenced by marks.

When interviewed, nine students (18%) mentioned that marks influenced their confidence, motivation and emotion toward learning biology and the others did not express their opinions toward this. The reasons they gave, for instance, good marks increased student F14's confidence and reinforced her motivation. In her words:

With good marks, I feel learning is easier. That subject will become the first one I am willing to study. Good marks give me a sense of achievement. As for the subject where I got a low mark, I am a little bit scared to study it and without confidence in it. I am unwilling to study that again (F14).

For example, student M4 actually disliked biology. However, motivated by the need to achieve, studying biology became his means to earn marks. When he got positive feedback from marks, he would study even more. He recalled:

The teacher's teaching was bad... I hated biology at first. But in order to cope with tests, I have to study biology. After I got a high mark, I like biology. In fact, it is not as difficult as I supposed (M4).

Student M5 felt upset because his biological knowledge was unable to earn marks. In his words:

Even though I have much biological knowledge, my biology mark did not increase because of that (M5).

To conclude, a majority of students reported a personal interest in biology, although around half admitted they were motivated by marks.

5.4.3 Comments about the current biology lecture classes

To explore student views of the current lecture classes, 523 students were surveyed about their perceptions of the weaknesses and strengths of the lecture classes (see Appendix 5 question 8). Their responses regarding the weaknesses are shown in Figure 5.2. The monotonous teaching approach was the main weakness raised by students (66%). Almost half of the students felt embarrassed asking or being asked questions in class (43%). This suggests there was little interaction in

their biology classes. Around one sixth of them agreed that lessons could not be applied in daily life (17%).

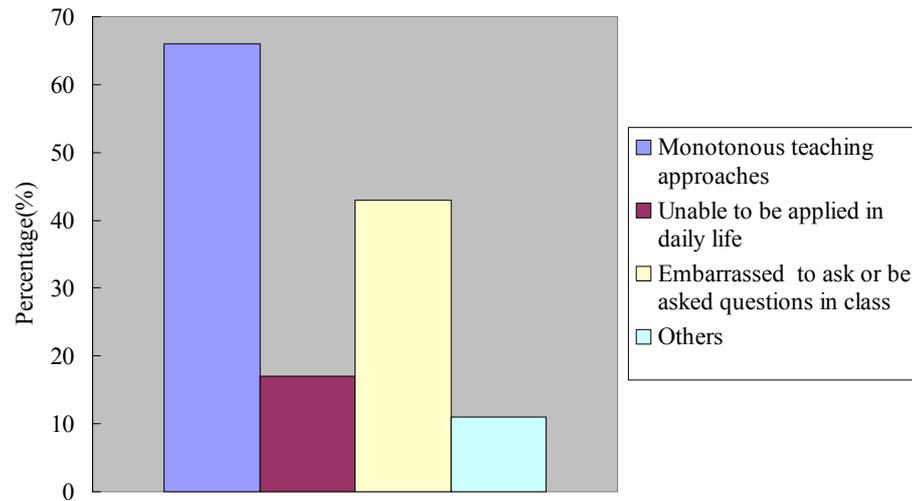


Figure 5.2: Student perceptions of the weaknesses of the present lecture classes (N=523)

As for the strengths of the lecture classes, closed responses to this issue are summarized in Figure 5.3. The students thought the present biology lecture classes were very efficient (65%) and believed the classes helpful to them in preparing for tests (40%).

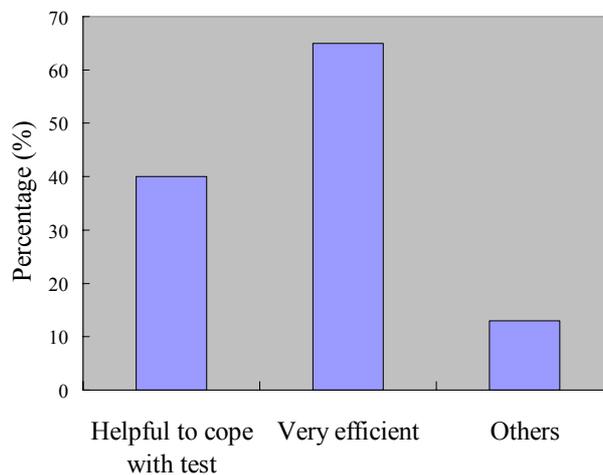


Figure 5.3: Student perceptions of the strengths of the present lecture classes (N=523)

With the same sample of students, a question was designed to find out to what extent the students were satisfied with the lecture classes (see Appendix Question 6(2)). Their responses are shown in Figure 5.4. Students were satisfied with them

(39%); a slightly higher percent (41%) held neutral attitudes. One hundred and four (20%) were dissatisfied.

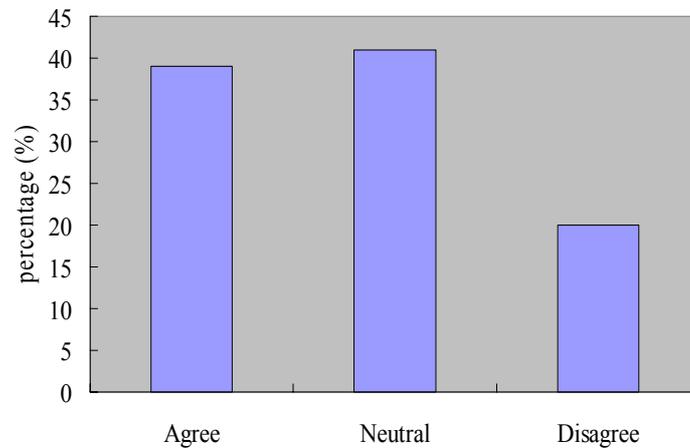


Figure 5.4: The extent of student satisfaction with the current lecture classes (N=523)

In short, a majority of the students perceived the teaching was monotonous and the teaching content was irrelevant to daily life. Students being afraid of asking or being asked questions suggested that there was a lack of a supportive atmosphere of interaction in the classes. The students perceived strengths suggested they believed that knowledge could be transmitted from the knowledgeable teacher to them and they also believed this was helpful in preparing for tests. The low percentage of student satisfaction with the lecture classes suggested that it was time to make changes.

5.5 Changes students would like to see in the lecture classes

A high percentage of students suggested teachers and their teaching approaches needed changes in the lecture classes. Students were interviewed about their ideas for change (see Appendix Question 14).

A variety of opinions provided by students were about changing teaching approaches. They were; the provision of more and updated knowledge, teaching including more various ways, offering more thinking time, linking to daily life and encouraging discussion (80%). The others were about teachers themselves (20%). Ten students expected their teacher to transmit more and up-to-date

knowledge which students needed because students were busy studying or attending cram school after school. One suggested:

Students needed to attend cram school or study hard after school. They have no time to grab extracurricular material, therefore, the teacher need to supply more as much knowledge as he/she could during lecture time (M18).

It seems that the students did not assume they could search for more information by themselves but put most of the responsibility on the teacher.

Students believed only teachers are experts. Whether they having better learning depended on the amount of knowledge they received. These can be seen in the following examples:

If teacher separates the students into several groups, each group reports one topic, they will only be familiar with their own topic, but can't absorb other groups' report thoroughly as they could absorb it from the teacher. The teacher's lecture is more authoritative and convincing for the students (M6).

In learning biology, the teacher plays an important role. They are experienced and provide well-organised notes for us. If we have good absorption of the lecture, we will learn well (M5).

The student quotes suggested that they considered that a good lecture plus rote learning guaranteed successful learning.

Ten students suggested using different teaching approaches, e.g. doing experiments or watching film and diagrams, to help their understanding of concepts. They also asked for more time for thinking and that the teaching content be linked with everyday life. Three representative suggestions were:

When the teacher teaches physiology or biochemistry, some experiments or films are necessary for us. Besides, he ought not to teach in an invariable way (F15).

I don't like the teaching approach very much. I hope I can see the diagrams and have time to think why these happened (M21).

Teaching content had better include two sets, one for practical use another for coping with tests. Moreover, teach something link to daily life (M10).

Interactions between teacher and students were considered by eight students to encourage discussion. For example:

The teacher and students take turns to ask questions in class time, so we can have discussions in class (F25).

Although students agreed that interactions in class would be good for their learning, four students thought they could not afford preparation time for the pressure of studying other subjects.

Interactions are good. However, if I take too much time on preparing for biology class, it can affect me by not having sufficient time to prepare other subjects. I am not unwilling to, but couldn't afford the time to use such an interaction (M8).

Another four did not value group discussion because it could be unfocused, distracting and inconclusive. One comment:

Group discussion may lead to chat and is unlikely to obtain conclusions due to too many opinions (F1).

Students would like more opportunities to think and to take part in discussions, and something about linking content to everyday life. Conversely, others students expected more knowledge to be given and had doubts about the extent to which students could play a productive role in lecture classes. Overall, students seemed to be divided with around half wanting more interaction and half not seeing any benefit in this.

Ten students suggested that teachers should possess some personality characters, such as being patient, concerned about and encouraging students, and having good eloquence to attract students and seeking for updated knowledge. For example:

Teachers should be concerned about the students and had better to read up-date material all the time (F15).

To examine the student expectations of a good teacher, their opinions were sought by questionnaire (see Appendix 5, question 7). The outcomes are displayed in Figure 5.5.

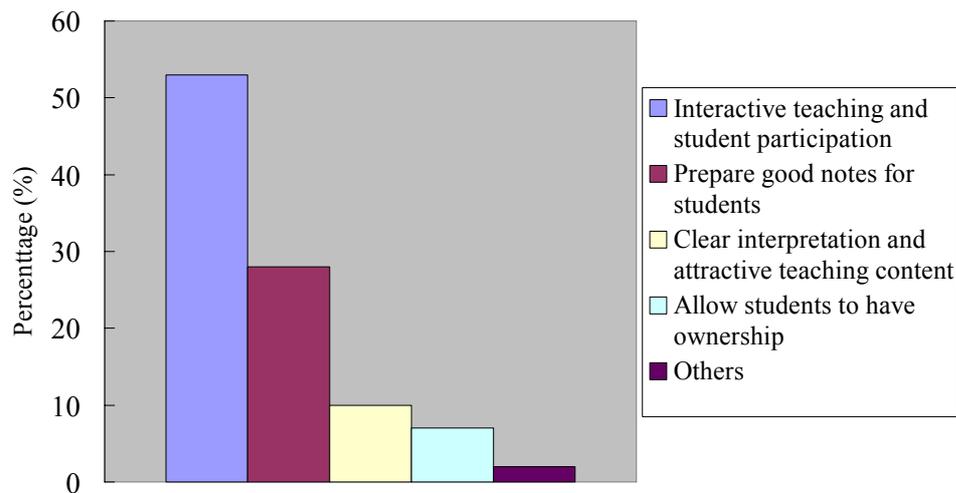


Figure 5.5: Student expectations of a good teacher (N=523)

More than half of the students wished their teacher to use interactive teaching (53%). The students might not have real understanding about interactive teaching, but merely hoped to have a teaching different from the current one, which could provide the student with more opportunities of involvement. Only 28% students reported that good teachers produced good notes.

5.6 Student thoughts about learning in the experiment classes

Student thoughts about learning in the lecture classes have been discussed in Section 5.4. In this section, student perceptions of what they could and did learn from doing experiments and their comments about the experiment classes are elaborated. The same classes were surveyed for both questionnaires (Q1A and Q1B); however, some students were absent when the second questionnaire was conducted. This led to the number of participants in Q1A (N=523) less than Q1B (N=485).

5.6.1 Student perceptions of what they could and did learn from doing experiments

To explore the student perceptions of what they could learn and what they did learn from the biology experiment classes, a survey was conducted (see Appendix 6, Question 7). The outcomes are listed in Table 5.4 from least to greatest difference. The students were allowed to have more than one choice.

Domain	The reasons the students thought they could learn or did learn from the biology experiment classes	What they thought could learn (%)	What they thought did learn (%)	Difference (%)
Pro.	Manipulating equipment	82	78	<i>4</i>
Pro.	Giving an opportunity for experiencing science	80	70	<i>10</i>
Cog.	For a lasting effect to cope with test	80	67	13
Aff.	Increasing friendship	<i>50</i>	34	16
Aff.	Promoting interest	74	51	23
Aff.	Feeling of reward	64	40	24
Aff.	Satisfying curiosity	73	47	26
Aff.	Becoming more patient, attentive and responsible	66	39	27
Pro.	Learning from errors or failures	69	41	28
Cog.	Realizing concepts being not more abstract but more real	87	58	29
Cog.	Verifying theories	77	47	30
Pro.	Cooperating and negotiating	71	41	30
Pro.	Judging from class discussion	64	32	32
Cog.	Making new discoveries	65	32	33
Cog.	Gaining more concepts	81	45	36
Pro.	Familiarizing oneself with the procedure of solving problems such as observing, making an hypothesis.	66	30	36
Aff.	Increasing creativity	<i>52</i>	<i>14</i>	38
Pro.	Enhancing the ability of thinking and analysing	71	<i>26</i>	45

Table 5.4: The details of percentage difference between what the students thought they could learn and actually learned from the present biology experiment classes (N=485)

- Key: (1) ‘Cog.’ represents ‘Cognitive aspects’; ‘Pro.’ represents ‘Process skills’; ‘Aff.’ represents ‘Affective aspects’;
- (2) **Bold:** represents most prevalent responses (based on rank);
- (3) *Italic:* represents least prevalent responses (based on rank).

A number of significant findings were obtained from Table 5.4. The table shows that the learning the students thought they could gain from the biology experiment classes, was all higher than what they thought they actually learn. For example, in the option *realizing concepts were not more abstract but more real*, the former is 87% and the latter is 58%; in the option *gaining more concepts* the former is 81% and the latter is 45%, respectively; and so on.

The process skills options important to the students were *manipulating equipment* (82%, 78%) and *giving an opportunity for experiencing* (80%, 70%). It appears that these two process skills were the main ones students perceived they did learn from the experiments and had the least differences when compared with what students thought they could learn. *Manipulation* is the lower level skill in science work. However, the other higher level skills such as *judging* (64% and 32%), *thinking, analysing* (71% and 26%) and *problem-solving* (66% and 30%) showed big differences between what the students thought they could learn and what they thought they did learn.

The cognitive option *for a lasting effect to cope with tests* (80%, 67%) also had a smaller difference. In addition to that option, the students had high expectations for the other cognitive outcomes as well, but the actual learning they thought was less, e.g. *realizing concepts were not more abstract but more real* (87% and 58%, respectively), *verifying theories* (77% and 47%), *making new discoveries* (65% and 32%) and *gaining more concepts* (81% and 45%).

The other, closer, differences belong to the affective aspects including *increasing friendship* (50% and 34%), *promoting interest* (74% and 51%), *doing a rewarding activity* (64% and 40%), *satisfying curiosity* (73% and 47%) and *becoming more patient, attentive and responsible* (66% and 39%). The only exception was *increasing creativity*. Although the experiments with predetermined procedure and outcomes were not greatly expected in *increasing creativity* (52%), the percentage of the option that students perceived learning from doing experiments was surprisingly low (14%). This suggested that experiments were considered to provide students with little opportunities to develop their creativity.

According to the student perceptions, it seems the senior high biology experiments are useful for enhancing manipulating equipment, for the experience, and for coping with tests; but not for gaining more concepts, for familiarizing oneself with the procedure of solving problems, for increasing creativity and for promoting high-order thinking. These suggested that their perceived learning outcomes were inclined to be at a technical level rather than a higher cognitive level and learning from doing experiments was mainly for preparing for tests.

5.6.2 Comments about the experiment classes

The student comments of the current experiment classes were sought from interviews and followed up by a survey. These areas investigated included prescribed experiments, equipment, student attitudes toward learning, teacher's role and class time and size. A survey was conducted to elicit student responses about the weaknesses and strengths of doing experiments; the extent to which they liked doing experiments and their satisfactions with the experiment classes (see Appendix 6; Questions 13, 1 and 6).

Prescribed experiments

Some of the interview students approved of prescribed experiments (27%) and others disapproved (22%). Students said they needed the teacher's demonstrations to save time, where clear instruction and outcomes were provided, there was no risk of making mistakes and no safety worries. For example:

The teacher needs to demonstrate at the beginning of the class. Without that, many variable factors will show up and lead to the work being out of control and troublesome. The outcomes may become very weird and can't be explained. Hence I like the teacher's demonstrations, which prevent me making mistakes. Making mistakes is wasting time and unsafe (F14).

Students perceived there was no need to make an hypothesis in doing prescribed experiments. Some of them took it for granted that making an hypothesis was a scientist's work and they regarded their experiment works as trivial. One explained:

I don't have to make an hypothesis before I do the experiment. Only scientists who do big tasks need to be making an hypothesis. I just do small ones (F8).

The other students disapproved of prescribed experiments and perceived that they were a waste of time and that they minimised student autonomy. When they simply followed instructions, they felt this did not lead to meaningful learning because the outcomes were pre-determined and few opportunities were provided to develop thinking skills and solve problems. Two students stated:

The teacher reminds us to avoid any chance of making mistakes, so we won't get different results. But in that way, we don't know how to find out and solve problems (M20).

We are just following the instructions and have no chance to think. In that way, I don't know why I do experiments (F13).

The above quotes suggest teachers need to think about whether when they take charge of student learning they actually do fulfil their duty to students as is emphasised in Confucian-heritage culture. It appears some students do not think such explicit guidance leads to effective learning

Only about half of the students commented on the nature of experiments. For all students, the type of experiment they would like to have will be explored in the next section.

Equipment

Students stated their attitude toward using apparatus was seriously affected by fear of causing damage. Also, they believed whether the equipment was available had an impact on the outcomes they would have (33%). Two said:

My teacher was worried the equipment would be damaged, so we were afraid of breaking it (F12).

Some types of equipment are old, broken or not available, so we can't get a good outcome (F26).

Student attitudes toward learning

Student comments indicated that many student learning attitudes toward doing experiments were passive (31%). Their purpose was to get the right answers by relying on teacher and peer information. They had no desire to explore the tasks on their own, but would rather spend time chatting and their chatting affected other student performance. Two complained:

Some students didn't do the experiments, but just wait to copy other's results (F15).

Sometimes student chats last a whole session and affect others (M23).

Teacher roles

Sixteen percent of the students highlighted the teacher's role (16%). Half of them stated their teacher was responsible for their learning which was consistent with the Confucian-heritage culture in Taiwan; one fourth of them held the opposite view; and the others complained the teacher insisted on the expected answer. Four students perceived their teacher was good, because they had done their duty in helping students avoid mistakes. One boy praised his teacher:

My teacher repeats the demonstration of the experiments until we know how to do it to make sure we will not make mistakes. If I cannot get data from the experiments, the teacher will find a resolution for me. That is faster than if I do it by myself. I feel she is really a good teacher (M3).

In this case, although the students perceived their teacher did much for them, it might take away their chance of having procedural understanding.

Conversely, two students felt their teacher had little concern about what they had learned because of a lack of interactions. One complained:

The teacher is perfunctory. He doesn't care about what we have learned from the experiments. I say this because there is no discussion about the experiments. The teacher should guide the discussion instead of saying nothing (F26).

Two students thought their teacher lacked flexibility in dealing with inaccurate results, which meant her students had to get a correct answer. One stated:

The teacher asks us to get the predetermined results. In case we don't meet her demand, we have to repeat it otherwise she will blame us. No matter what explanations we give, the teacher won't accept them (F4).

This suggested that student learning can be affected by teacher beliefs.

Class time and size

Students perceived there was limited class time (16%) and big class size (12%). The students commented they could not get expected results in time therefore they had to copy the right answers to avoid a low mark. One said:

In case we didn't have enough time to finish the experiments, we cannot help but copy the teacher's results on our workbook (F23).

Also students complained that a big class size might cause students to have less chance to perform experiments than a small class.

Weaknesses of the present experiment classes

A survey was conducted to investigate student perceptions of the weakness of the current experiment classes. Their responses are ranked by decreasing order and presented in Table 5.5. Students are allowed to tick more than one option.

Weakness	Occurrence (N=485)	Percentage (%)
Little autonomy	276	57
Time constraints	270	56
Unrelated to daily life	269	55
Experiments following instruction providing little opportunity to stimulate thinking	267	55
Few experiments	260	54
Little discussion at the end of an experiment class	255	53
Old and broken apparatus	203	42
Assessments need to be improved	195	40
Too many students in a group to do experiments	149	31
Often being interrupted by classmates	141	29
The experiments are too simple to enhance creativity	115	24
Others	6	1

Table 5.5: Student perceptions of the weakness of the present biology experiment classes

Table 5.5 shows that more than half of the students (53%-57%) thought that the experiment classes provided for no autonomy, were limited by time, were unrelated to daily life, provided little opportunity for thinking, provided low frequency of experiments and allowed little to no discussion at the end of an experiment class. About 24%-42% of the students indicated other weaknesses which were that the equipment was old, there was a need for better assessment, group size was too big and experiments too closed. It appears that the experiments were not requiring students to take learning responsibility, isolated teaching from

the real world, did not provide students with thinking opportunities and lacked interactions.

Strengths of the experiment classes

Student perceptions of the strengths of the experiment classes are illustrated in Figure 5.6. Over three-quarters of the students (76%) perceived that the biology experiment classes were helpful in preparing them for tests. In other words, the real experience helped them in the retention of knowledge. About half of the students (52%) considered they had sufficient equipment to use. Students also reported the strength lay in following instruction and being able to avoid making mistakes (44%).

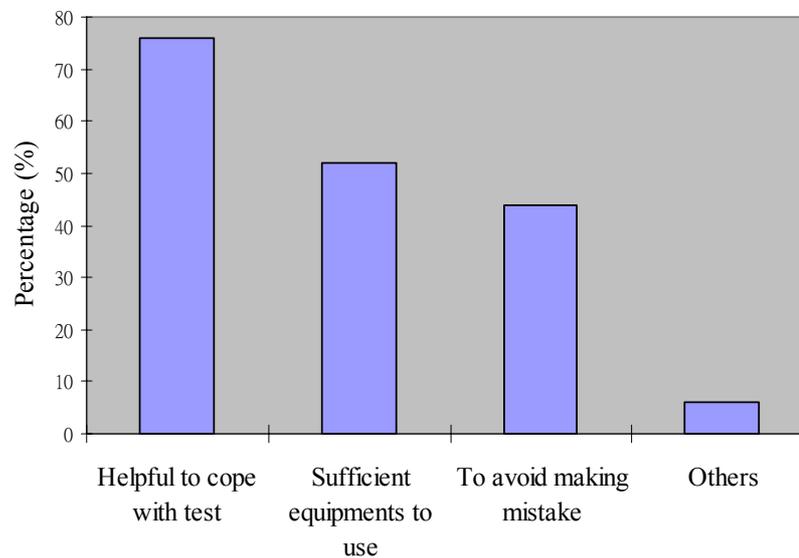


Figure 5.6: Student perceptions of the strengths of the present biology experiment classes (N=485)

Again, as student response to the strengths of their lecture classes (see Section 5.4.3), doing experiments was ticked by most of the students with very high percentage in the item ‘helpful to cope with tests’.

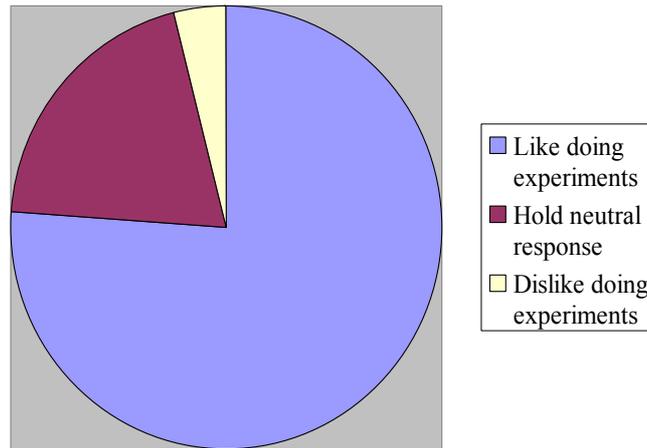


Figure 5.7: Student perceptions of doing experiments (N=485)

As Figure 5.7 shows, over 70% of respondents acknowledged they like doing experiments and 30% were not sure or disagreed.

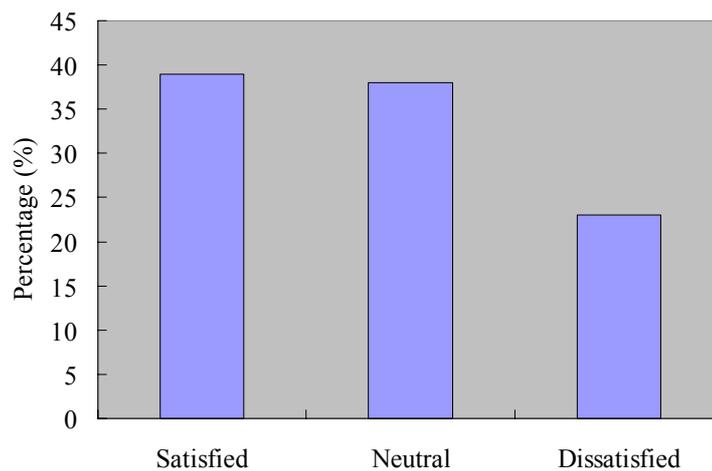


Figure 5.8: The extent the students were satisfied with the current experiment classes (N=485)

As Figure 5.8 illustrates students indicated they were satisfied with the class (39%). The other students were neutral (38%) or explicitly expressed they were not satisfied (23%). The result is similar to the extent the students were satisfied with the current lecture classes (see Section 5.4.3 and Figure 5.4).

To summarize, around one quarter of the interview students approval of prescribed experiments and another quarter disapproved. Students indicated the availability of equipment affected their learning outcomes when doing

experiments. Their descriptions of what their teachers had done for them suggested they might lose the opportunity of the gaining procedural understanding. Students were frustrated they had to get the teacher expected outcomes. Survey outcomes showed that the experiment classes provided students with little autonomy, limited time, experiments irrelevant to daily life and little chance of stimulating thinking and discussion. However, these classes were helpful in coping with tests. The majority of the students liked doing experiments. However, less than forty percent of the students were satisfied with the current experiment classes.

5.7 Changes students would like to see in the experiment classes

Student perceptions about the changes they would like to see in the experiment classes are listed in Table 5.6. Seven categories of the changes are presented in decreasing order (some students cited more than one change).

Category	Percentage (%)
Changes in the nature of experimental work	57
Changes in the teaching approaches	29
Cooperation and discussion	20
Relevance to daily life	20
Changes in Assessment	16
Others	10
Without specific suggestions	8

Table 5.6: Student perceptions of the changes they would like to see in the future experiment classes (N=49)

5.7.1 Changes in the nature of experimental work

Over half the students talked about changes they would like to see in the nature of experimental work (57%). Most of them preferred to see more student autonomy in the classes, however, a minority would rather have prescribed experiments. Most students hoped to see more student autonomy and suggested that learning content needed be more student-controlled than teacher-directed. A representative comment was:

The teacher doesn't have to arrange every detail of the experiment class for us. She may just give the problem and important points, and then come to assist when we need her (F13).

One student described his experience in eighth grade as an example to illustrate the benefits of less prescribed, more open experiments. In his words:

We had a monographic study in eighth grade. We looked for the title, designed the experiment, and then did it by ourselves. We did the experiments in biology class time and after school. If we had problems, we could consult the teacher in class time. We borrowed equipment from school and designed the experiment after a discussion. It took lots of time. In that type of activity, at least we knew how to design an experiment, discuss it with other classmates and do a written and an oral report. Also, it enhanced our ability in thinking, searching for information and discussion (M10).

Four students believed their own ability but doubted other student abilities in carrying out activities that allowed for more students autonomy. One said:

I would like to try activities with more autonomy, but for those less able or lazy students it may be not a good idea (F4).

Even though they approved of less prescribed activities, five students still wanted to know the right answer. For example:

Before the class is dismissed, our teacher should give us the 'right' answer to cope with the test (F24).

In contrast to these students, five students would rather do prescribed experiments. The pressure of UEE led them to feel that they could not afford and/or were unwilling to spend time on experiments which required them to take responsibility and/or could lead to their making mistakes. Two students explained:

Unless the UEE is abolished, I have no time and no desire to spend time in designing (F23).

Most students will feel troubled, if the teacher only provides the problem. They would rather the teacher offered the answer (F10).

Another reiterated:

Following instruction is necessary. If I make a mistake, I will pay a high price for it, so I need to be careful when I do experiments (M3).

These quotes support the idea of collectivism made students focus on earning good marks (Section 2.2.1).

To gain a broader picture of student ideas about the type of experiment they were doing and liked, two questions were included (see Appendix 6, Question 11) and their responses are shown in Figure 5.9.

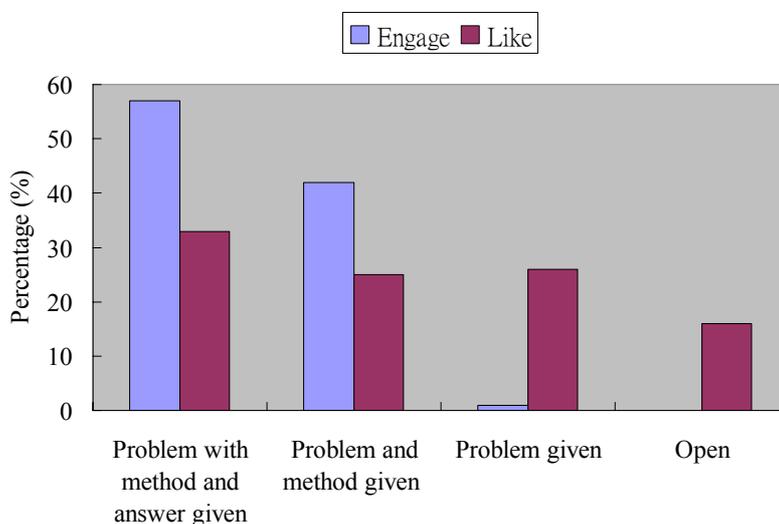


Figure 5.9: The type of experiment the students perceived they actually engaged and liked in the biology experiment classes (N=485)

Figure 5.9 indicates the type of experiment with increasing degrees of openness from left to right. Students perceived they were actually engaged prescribed work in which the problem, method and answer were given (57%). The other students said they were engaged activities where the problem and method were given and the answer was left open (42%). Very few students (1%) reported experiments with only the problem given engaged them; perhaps they meant the experiences of science fair.

Around one-third of the students declared they preferred prescribed experiments in which the problem, method and answer were given (33%). A quarter of the students liked both the problem and method being provided and the answer left open. A similar percentage of the students ticked the option ‘problem given’ (26%). Only 16% students opted for completely open work, in which the problem, method and answer were all left open. In other words, around two-thirds of the students (67%) said they liked experiments which were more open than most of those they currently experiencing.

To sum up the interview and survey outcomes, although almost all the students perceived they had been engaged closed experiments where problem, method and answer were given, or problem and method were provided, about two-thirds of them liked more or completely open investigation. However, some of them doubted whether students had ability and skills to do open work and worried about preparing for tests if they perform open work.

5.7.2 Changes in the teaching approaches

Students suggested that their teacher provided prompt help and give a demonstration at the beginning of an experiment (22%). Eight students asked for the teacher's assistance during their doing of experiments. One suggested:

I hope to see the teacher walking around groups to give help instead of sitting on the chair all the time. We need his help (F1).

It appears that some students would like the teacher to interact more with them and play the role of a helper in doing experiments.

The other three students asked for teacher demonstration of the use of apparatus at the beginning of an experiment class, because that made them feel more secure. For example:

We worry about safety. Also, if there is no teacher demonstration, we might miss some steps (F23).

It seems that the students relied heavily on their teacher in a manner consistent with Confucian-heritage cultural norms of student-teacher roles.

5.7.3 Cooperation and discussion

A few students suggested student cooperation and discussions in doing experiments (20%). They recommended learning through sharing ideas and reaching a consensus. One student described:

I like to work with peers who were not onlookers in doing experiments. We can express our own opinions and decide whose can be accepted (F24).

One student suggested teacher could guide this sharing:

At the end of an experiment class, there must be a teacher-led whole class discussion. Everyone observes from different angle, and then a whole picture is formed (F25).

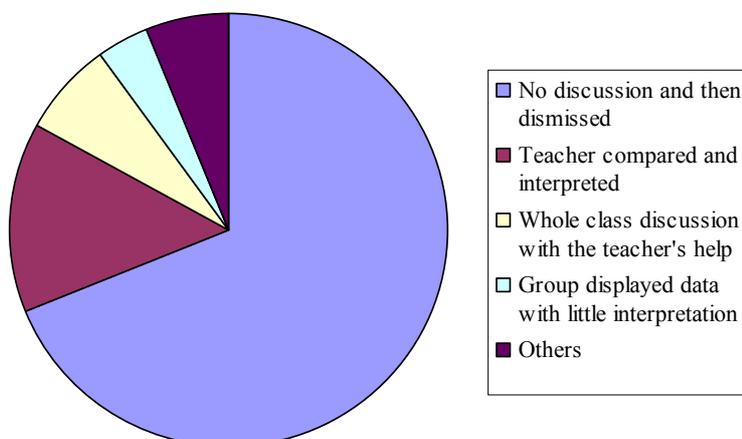


Figure 5.10: Student discussions at the end of the experiment class (N=485)

As Figure 5.10 shows 69% of the students declared they did not have any group or whole class discussion at the end of an experiment class. Fourteen percent stated their teacher compared their data and made an interpretation for them before the class was dismissed. The other responses had a low percentage.

The significant lack of discussion at the end of an experiment class suggests that the purpose of biology experiment classes was to complete the task rather than for students to interact with the teacher and peers to make sense of their experience in the classes.

5.7.4 Relevance to daily life

Ten students (20%) wanted the teacher to supply them with up-to-date knowledge and show them life applications. One suggested:

Give life examples and new knowledge and tell us how they relate to our daily life (M10).

They wished their teachers offered more interesting and practical activities at their level. One explained:

The teacher provides some topics relevant to our life experiences, not too difficult or beyond our abilities, more interesting (M16).

To explore whether students agreed that doing experiments achieves knowledge but does not help application in everyday life, a survey was conducted (see Appendix 6, Question 4). As Figure 5.11 illustrates, the data showed that 61% of the students thought they obtained knowledge rather than life applications by doing experiments. Less than 40% disagreed with that. It appears that the biology knowledge was not real to the students.

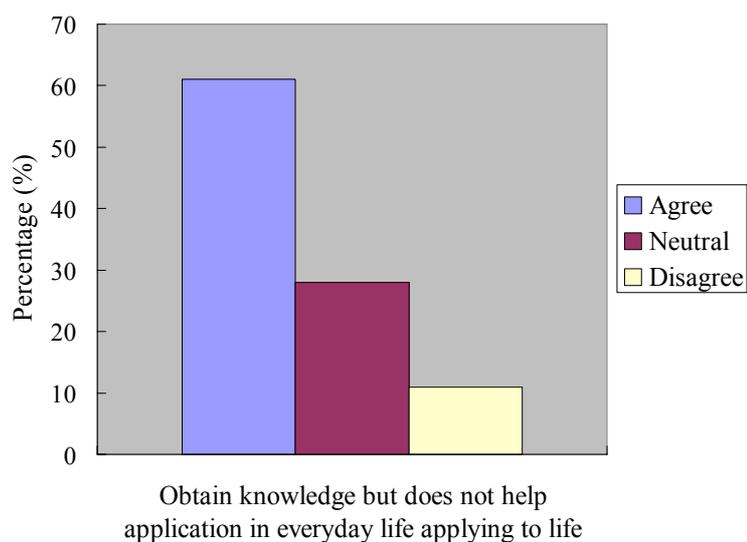


Figure 5.11: Student thoughts about doing experiments (N=485)

5.7.5 The assessment

Eight students (16%) had suggestions in regard to assessment. Normally, teachers use external written tests to assess student understanding. The student suggested that the teachers assess their attitudes and the learning process, e.g. how they think. They hoped for change in the emphasis and content of assessment. For example:

I hope that the teachers can change their ways of assessment. During the process, the students may have good ideas, but the teacher won't know. Therefore, the assessment emphasizing the experiment's outcomes is questionable. Normally, if I get an unexpected result, I have almost no chance to explain it (F15).

The options *others* and *without specific suggestions* had few responses.

To sum up, about two-thirds of the students liked more or even completely open work. They wanted more autonomy and more assistance from their teacher. However, some of them had little confidence in their own ability and had difficulties in preparing for tests. The students suggested more collaboration and

discussion which were severely lacking in their current experiment classes. They also wanted more life application and diverse assessments.

5.8 Summary of student perceptions of biology learning and teaching

The main reason for students taking biology was to increase entry options to university, which is an extrinsic motivation for learning biology. Under the structure of the current classes, and consistent with a focus on examination pressure from UEE, the learning approaches the students used most often were those they thought could increase their marks, such as using test books and practising repeatedly. These were also the approaches they most disliked.

The demands of assessment which supported the need to rote learn large amount of material were perceived to lead to the main learning difficulties. In the view of some students, the one right answer nature of assessment disengaged them from thinking. Students perceived that biology concepts had few links with their everyday life which led to their feeling that these concepts were abstract and not meaningful, this being another difficulty to them. Most students reported a personal interest in biology, although around half admitted they were motivated primarily by marks. A majority of the students perceived the lectures were boring and the teaching content was irrelevant to daily life. However, they were helpful in preparing for tests. It appears that there was a lack of a supportive atmosphere of interaction in the classes because students were afraid of asking or being asked questions. Students hoped their teacher transmitted more knowledge, which implied that the students put most responsibility for their learning on the teacher rather than on them. That might be relevant to the belief that teachers were more reliable in providing accurate knowledge than students. Less than 40% of the student satisfied with the current lecture classes, which supported the need to make a change. Students indicated they would like lecture class teaching to provide more opportunities for thinking, more discussion and more links to their daily life.

It seems the senior high biology experiments are useful for enhancing manipulation and for coping with tests; but not for gaining more concepts, for familiarizing oneself with the procedure of solving problems, for increasing creativity and for promoting high-order thinking. The student comments about experiments suggested that their perceived learning outcomes were inclined to be at a superficial technical level rather than a higher cognitive level. Students indicated the closed experiments allowed for little student autonomy, lacked links to daily life, and had little chance of stimulating thinking and little discussion. They were seen as helpful to cope with tests. The students stated they were frustrated when the teacher insisted they reproduce the expected answer. Again, less than 40% of the students were satisfied with their current experiment classes. They expressed a preference for more experimental work. In particular, based on the survey outcomes, nearly two-thirds of the students would like to have more or completely open experimental work. This suggests they might support more open work, although some indicated they lacked confidence in their abilities and skills, and worried about the dominance of examinations. Furthermore, they hoped for more experiments relevant to their daily life, more assistance from the teachers, more student cooperation, more time for class discussion and a change to focus assessment on the process of doing experiments rather than the product.

Based on the student interview and survey data, the students were more likely to use memorizing as a learning approach and to learn by manipulation from experiments rather than develop the abilities to think and analyse data. It seems that student learning could not reach the goals set in the senior biology curriculum in Taiwan. The data reported in this chapter provide with some hints about how to improve the teaching and learning in classroom settings. Emerging from the study, is the following question: Do the teachers have similar perceptions in teaching and learning in biology as students?

Chapter 6

The teacher perceptions of biology teaching and learning

6.1 Introduction

Within an interpretive paradigm, it is acknowledged that different participants have different interpretations of the social world. Chapter 5 explored student perceptions of the lecture and experiment classes. The perceptions of teachers can be quite different from those of their students (Lorsbach & Tobin, 1995; Wilkinson & Ward, 1997). Some researchers suggest teacher interviews coupled with student interviews and questionnaires can provide information about linkages between teacher and student beliefs (Lyons, 1990; Schoenfeld, 1992). Therefore, in this study, in addition to the student interpretations, the teacher perspectives needed to be investigated to better understand student learning and teachers' own teaching experiences.

The purpose of this chapter is to outline what teachers believe about their teaching and student learning in the lecture and experiment classes and to compare teacher perceptions of biology classes with those of their students. Twelve teachers from eight senior high schools participated in an interview, face to face or via telephone (see Section 4.4). For the teacher interview questions see Appendix 3.

The teacher perceptions of biology teaching are described in Section 6.2. Insights into the teacher perceptions of student learning in biology classes are in Section 6.3. For the design of a future intervention, the researcher would like to know the teacher perspectives on interactive teaching and open-ended experiments. Their thoughts are revealed in Section 6.4. A summary of teacher perceptions of biology teaching and learning is presented in Section 6.5. Argument and suggestions for an intervention are outlined in Section 6.5.

6.2 Teacher perceptions of biology teaching

In this section, the teacher views of the main barriers they encountered in teaching biology, the teaching approaches and the most useful of those they employed in the biology lecture classes, and their criticisms of the lecture/experiment class structure are detailed.

6.2.1 Teaching difficulties

The teacher opinions about their difficulties in teaching practice are summarised in Table 6.1.

Teaching difficulties	Occurrence (N=12)
Passive, unenthusiastic students	12
Issues of understanding and knowledge	8
Limited resources	5
Covering the syllabus	4
Assessment	3
Textbooks	3
Classroom management	1

Table 6.1: Teacher perceptions of teaching difficulties

Passive, unenthusiastic students

All twelve teachers criticized students learned passively and unenthusiastically. They perceived the students were reluctant to think, dozing in a class, low learning motivation and being motivated by examinations. Five of them commented students passively received teacher knowledge and made little responses in class due to a lack of thinking. Teacher T1 explained that this perception lead her to use repetitive exercises as a means of meeting her responsibility to help her students pass examinations. In her words:

The students learn passively. They are unwilling to think. Each time I posed a question to them, they didn't have any responses. For the Grade 12 students, I need to leave them time for repetitive practice. My responsibility is to help them pass the entrance examination. More discussion is impossible (T1).

Teacher T3 noted that students considered that too much thinking could cause them to write down an answer different from the right one. Thus, this led to

students not use thinking as a learning strategy. This explanation is congruent with the view of some of the students (see Section 5.4.1). Teacher T3 said:

The students said if they use intuition to cope with tests, they are often correct. But if they think too much, they might have the wrong answers. They perceived that they need to recall much of the content of biology (T3).

Four teachers complained that students' dozing in class was a widespread practice and that this phenomenon affected their enthusiasm for teaching. Teacher T7 commented:

I can't wake up the dozing students in my class. Even when I ask them to wash their faces; they will doze again after going back to their seats. I felt frustrated. Students doze in every class (T7).

Three teachers reported students had low motivation for learning biology. This too was said to affect teacher own motivation. Teacher T11 explained:

About one third students in the third group had little learning motivation, which made me frustrated, and I didn't know how to stimulate their interest (T11).

Teacher T5 commented that students were mainly motivated by examinations. She said:

The students don't study after school, unless there is a test next day (T5).

Teacher T9 reiterated that without the external examination, the students might lose motivation and teachers would confront another crisis in teaching. She said:

Without the pressure of entrance examination, teachers might have more pressure, because they need to find more teaching materials. However, the most difficult thing is not that, but how to promote student motivation to study. If the entrance examination is abolished, no student will stud (T9).

A reason gave by teachers to explain student passive learning was that most students attend cram school after school and the school takes over student learning responsibilities and encourages memorizing. Teacher T6 commented:

The students go to cram school to get organised learning materials and practice repetitively because of a lack of confidence in dealing with tests. (T6).

Issues of understanding and knowledge

Eight teachers raised issues to do with their own understanding and knowledge. Some of them thought they needed to have in depth content knowledge, some considered they were required to teach students how to gain knowledge and the others asked for further teacher education. Two were concerned about their lack of

content knowledge when encountering talented students asking them questions. Teacher T12, for example, lacked confidence when she was unable to provide student with straight answers. In her words:

I feel I am stupid. The students pose lots of questions, but I really don't know how to reply (T12).

In contrast, three teachers queried whether they needed to know and teach everything. Teacher T3 said:

I am not a knowledgeable teacher. I might be good at physiology, but I know little about botany. The students rely on me, which makes me feel very exhausted. I can't take all responsibility for student learning. I am not good at every biology field, but I have to teach like an expert. Is that a teacher's duty to teach everything to the class? I really cannot accept that (T3).

Three teachers said they had had little chance of teacher education or opportunity to approach experts to update their knowledge. Even if they got the chance of further education some teachers were forced to give it up, because the time given was often in a weekday. Communication between senior high school teachers and university professors was rare so there was little assistance from the professors. For example:

When I have problems with teaching content, I hope the university professors can offer a resolution, but I don't know how to approach them (T11).

Teaching resources

Five teachers complained they had limited teaching resources, such as models, specimens, illustrations and audio-visual equipment. Furthermore, they had the problem of seeking out these resources. For example:

Teaching resources are hard to find, such as videotapes or specimens (T12).

They also stated they needed a number of journals or books as references to inspire them in designing teaching activities.

I do not know what I should teach sometimes. I need some information e.g. journals (T6).

Covering the syllabus

Four teachers indicated they have the responsibility to provide students with supplementary work and ensure they covered all the material that might appear in the tests. For example:

I must teach every detail which shows up in the textbook. Otherwise, if these details appear in tests, they will blame me for not teaching. Actually, they can read by themselves and there is no need for me to elaborate (T3).

Assessment

Using commercial test sheets to assess students is a common practice in secondary school classroom settings (see Section 2.3.2). It saves teacher time and mental effort in devising questions for tests. Although the teachers were dissatisfied with the design of many questions on these sheets, they had no inspiration or vigour to develop a question bank for use with the fortnightly quiz. Three teachers explained their difficulties in assessment in a similar way as Teacher T9:

I don't like to use commercial test sheets to evaluate the students, but I have no other choices. Constructing the questions of a test is time consuming (T9).

The two remaining teaching difficulties of access to textbooks and classroom management attracted little comment and are not discussed here.

To sum up, the major obstacles that the teachers reported were student reluctance to use thinking as a learning strategy and a low motivation for learning. The teacher belief that they should teach all the knowledge students needed for examinations left them feeling exhausted. The lack of opportunity for teacher education was a problem in updating teacher knowledge. There were limited resources to inspire the teachers in teaching practise and to support teaching and assessment of student learning. Meanwhile, they had pressure to cover the syllabus.

6.2.2 Teaching approaches and ways that most useful to teach in the biology lecture classes

The researcher was interested in how the teachers taught and what ways were regarded as most useful by them. The teacher opinions about the most commonly used and the most useful ways for teaching biology are shown in Table 6.2 below.

Ways often used to teach biology	Ways most useful to teach biology
Transmission way (Occurrence)	Transmission way (Occurrence)
(1) Lecturing and clear notes 5	(1) Explicit lecture and clear notes 6
(2) Same as above, plus multimedia 3	(2) Same as above plus audio-visual 3
Mix ways	Interactive way
(1) Lectures & question-and-answer 3	(1) Question-and-answer 1
(2) Lectures & student activity 1	(2) Theme teaching 1
	(3) Discussion and presentation 1

Table 6.2: Teacher perceptions of the most frequently used and most useful ways of teaching biology (N=12)

Eight of 12 teachers provided the students with lectures and clear notes. Five of the eight teachers expected that ‘if they prepare a set of organised and clear knowledge, their students will absorb it well’, so they chose transmission as their teaching approach. This was said to help students cope with tests.

I prepare clear outlines and notes for the students to absorb to cope with tests (T9).

Three of the eight teachers employed multimedia to supplement lectures. One of them noted that this could activate student interest in the process of absorbing knowledge; hence she strongly recommended it along with lectures:

I use detailed notes on the blackboard and videotapes to help the grade 11 students. The notes help the students get better academic achievement and the videotapes stimulate their interest (T11).

Four teachers were not satisfied with only using lectures as a teaching approach and often used mix ways to teach biology. On the one hand, they taught their students how to deal with test via lectures and outlines. On the other hand, they sought to elicit student responses by posing questions and encouraging student reflection. One explained:

Mostly I use the transmission way. I prepare clear outlines and notes for the students to cope with tests. Sometimes I adopt an interactive way. I will use incentives or pose easy questions to the silent students to encourage them to reply to my questions (T6).

One of the four teachers perceived ‘explicit lecture and clear notes’ is most useful to teach biology. The other teachers commented the interactive way is the most useful to teach biology. For example:

I provide students with lectures, but sometimes I divide the students into groups, and then have discussion. That’s most helpful. (T9)

Three types of interactive ways were supposed to be useful in teaching biology; question and answer, theme teaching, and group discussion and presentation. There were little regarded by the teachers because of the time they took.

To conclude, a transmission teaching approach especially lectures and clear notes, was seen as most useful and adopted by most of the interviewed teachers.

6.2.3 Teacher criticisms of the lecture/experiment class structure

Teacher opinions about the weaknesses and strengths of lecture and experiment classes are discussed in the following section.

Weaknesses of the current class structure

The teacher views of the weaknesses of the lecture and experiment class structure are summarized in Table 6.3. The teachers raised seven points of weaknesses; most of the weaknesses were to do with the experiment classes.

Category	Occurrence (N=12)
Lack of openness of experiment	5
Different textbooks have contradictory content	3
Time constraints	3
Poor quality equipment	2
Teaching approach could not promote understanding	1
Class size too big	1
Lack of resources	1

Table 6.3: Teacher views of the weaknesses of the current biology classes

Five teachers considered that in the experiment classes the experiments did not offer students any chance to think and were actually ‘exercises’ instead of

‘investigations’. The recipe-type experiments only allowed the students to practise manipulation. The teachers considered the students found the experiments too easy and not worth discussing.

I don't think the current experiment is an investigation. The students only learn manipulation (T4).

The students will only remember the results of the current investigation and learn manipulation. Even if we have time for discuss, the students won't feel it worth discussing. Because the questions outlined in the laboratory manual are too simple (T3).

Three teachers made the criticism that the content of textbooks from different publishers was contradictory. Many new textbooks, based on the same curriculum, were published in 1999. Comparing with the previous textbook which had only one standard edition, the content of the textbooks from different publishers was inconsistent. The teachers complained they did not have a unified criterion to follow in teaching content. The teachers perceived the new textbooks offered breadth rather than depth, which made covering the syllabus nearly impossible.

A contradiction exists in 'one curriculum with different edition of textbooks'. I don't know which one is correct and to what extent I should teach. Besides, too much content needs to be taught (T11).

The selling prices of the new textbooks are several times that of the old ones, which might burden students who came from a poor family. In addition, the new textbooks increased the proportion of biochemistry and the teachers speculated that students would have difficulty in learning this portion because of a lack of chemistry background knowledge.

The students don't have sufficient prior chemistry knowledge to understand biochemistry of the new textbook (T9).

A criticism from three teachers was that it was not feasible to do experiments in a session of one-hour. The time merely allowed students to do manipulations rather than discuss what they had done.

The time for doing an investigation is too short. We have no time for discussion. One hour for investigation is not enough. I have no way other than to tell them the results so as to finish the investigation (T3).

The remaining variables attracted few comments and will not be discussed.

Compared with the student perceptions of the weaknesses of current biology classes (see Section 5.4.3 and 5.6.2) there were some differences between the statements of the teachers and students as follows:

- (1) students stressed the weaknesses of the lecture classes were; the teaching approach was monotonous, which encouraged them to doze in the class, and the teaching content was not applicable to their daily life. However, the teachers placed great emphasis on the textbooks. Perhaps, this was because the teachers had just begun using the new textbooks and were impressed by them and the interviewed students still used the old edition of textbooks; and,
- (2) both the students and teachers had the similar responses of the weaknesses of the experiment classes. They pointed to closed experiments, time constraints, equipment shortcomings and large class size.

Strengths of the current classes

The teachers identified three strengths of the current classes. They are; teaching is easy to prepare and efficient, the new textbook is good, and they provide a chance to practise skills.

Six teachers acknowledged that if they taught in a traditional way, the teaching was relatively easy because there was no need for further preparation.

The teacher will have less pressure with no need for spending time in designing the teaching and experiments (T4).

One of the six teachers mentioned that if the students studied as per their schedule (the teachers planned a test schedule with an assigned range of textbook pages) their learning would be guaranteed. In other words, the traditional way made teaching and learning straightforward.

If the students follow the review schedule that their teacher made for them, they won't have a problem with the coming entrance examination (T11).

In contrast to the points made earlier, four teachers believed the new textbooks offered better illustrations and appreciated having more options in the choice of biology textbooks.

The graphics and tables in the new textbook are good (T9).

The teaching content in the new revision are more substantial than in the old textbook. It's good that we have more choice of new textbooks. Five editions are provided now (T12).

Two teachers judged that students had a good level of manipulating skill through doing experiments and thought students should have the fundamental skill for entering university.

A closed experiment is still a good way to provide the students with the opportunity of practicing manipulation before entering university (T6).

Comparing the student perceptions of the strengths of the current biology classes (see Section 5.4.3 and 5.6.2) with the teachers', the differences are:

- (1) the students thought the current lecture classes were helpful to cope with tests and time efficient in gaining knowledge. The teachers did not mention tests but perceived time efficiency in teaching; and,
- (2) the students thought the current experiment classes were helpful in dealing with tests and preventing mistakes. The teachers considered they could only help the students be familiar with basic manipulating skill.

Both the student and teacher comments identified more weaknesses than strengths in the current biology classes.

6.3 Teacher perceptions of student learning in biology

After providing a succession of details about teaching in biology, the teacher opinions about student learning in the biology classes were investigated. They were asked for their perceptions of why students chose biology and student approaches to learning biology.

6.3.1 Teacher thoughts about why students choose biology

The teacher perspectives of the reasons why students take biology are shown in Table 6.4. The teachers were able to cite more than one reason.

Reasons students are taking biology	Occurrence (N=12)
For interest	10
For future careers	9
For increasing entry options	8
Being influenced by someone	7
For perceived ease of learning	6

Table 6.4: Teacher views of the reasons why students take biology

The teachers perceived the top two reasons the students took biology were for interest and future careers. Although interest was ranked high (the second), future careers were merely ranked the fifth on the student list. It seems that future career was emphasized more by teachers. Increasing entry options was ranked the third, which was ranked the top one by the students. Fewer of the teachers considered students to be influenced by someone and that their students took biology for perceived ease of learning.

The teachers predicted that the students who took biology for increasing entry options might not succeed in the University Entrance Examination (UEE) because they were half-hearted. Once Grade 12 students sensed they did not have sufficient time to cope with UEE, they would study other subjects during biology class time. This type of student did not show any determination in learning biology and the uncertainty caused them to fail to focus on biology learning or even to doze in class. Teacher T1 made this point very clearly:

The grade 11 students, who take biology for increasing entry options, often give up studying biology in Grade 12 for lack of time. They had better to change to another group; otherwise they might fail due to not concentrating on biology (T1).

Also the emotion was contagious in that it had a negative influence on other students in the same class. Teacher teaching enthusiasm was also affected by this student attitude.

Some of the Grade 12 students who decide to give up biology but still stay in the class affect the students who are uncertain of their aptitude. This influences the study atmosphere of the class. When I saw this type of student studied other subjects or dozed in my class I felt very frustrated (T11).

6.3.2 Teacher thoughts about student approaches to learning biology

A summary of the approaches (including the most useful approaches) teachers considered students use to learn in biology are listed in Table 6.5. The teachers cited more than one way.

The approaches	Occurrence (N=12)	
	(1) now using	(2) most helpful
Listening to lectures	7	3
Copying notes	4	0
Consulting teachers (in or after class)	3	0
Completing practise exercises	2	0
Watching videos or TV science programmes	2	0
Learning from press media	2	0
Accessing the Internet	2	1
Reading biology-related books or magazines	1	3
Reading textbooks	1	1
Doing experiments	0	1
Raising a pet or growing plants	0	1
Out of school visits (e.g. museum, botanical garden...)	0	1
Attending a biology club	0	1
Writing or oral reports	0	2
No specific approach	0	1

Table 6.5: Teacher views of the approaches and the most useful approaches used by students for learning in biology

Key: (1) Teachers perceptions of the approaches students use to learn biology;

(2) Teachers perceptions of the most useful approaches students use to learn biology.

The approaches the students use to learn biology

The teachers perceived that *listening to lectures*, *copying notes*, *consulting teachers* and *repetitive practising* were the approaches the students used to learn biology. Seven teachers supposed *listening to lectures* was the approach most

students used to learn and considered the teachers should take over student learning responsibilities. Two quotes illustrate the two points respectively:

They listen to the lecture attentively to learn biology (T8).

What the students learned depends on what the teachers provide (T2).

The last view was congruent with student's view. In Section 5.5, students also indicated their quality of learning depended on what the teacher provided for them. Both students and teachers put learning responsibilities on the teacher.

Four teachers believed that students copied notes consisting of organised points that were most likely to appear in quizzes or term examinations, and thus could prepare the students for tests,

Students rely on teacher's notes to earn marks (T9).

Three teachers assumed the students learned from their provision of explicit answers to student questions.

They also learn from asking the teacher questions after class (T8).

Two teachers mentioned that repetitive practises were frequently used by the students to earn marks. Swot books (with supplementary material and quizzes) or sheets (with quizzes) for each subject were sold in bookstores everywhere. Purchasing these could be a financial burden to the parents.

The students commonly use repetitive practise and their parents have to spend much money on buying those materials (T10).

A small number of teachers identified students accessing a range of other sources of information such as *watching the TV, the press media and the Internet*.

The approaches most useful for learning biology

The teachers perceived the most useful student learning approaches were *listening to lectures, reading biology-related books or magazines and written reports or presentation*. Generally speaking, Taiwanese society defines whether students have learned well on the basis of academic achievement in tests (see Section 2.3). If this was the goal, three teachers regarded *listen to lectures* as the most useful way to learn biology.

If useful means to help them get good marks, then the best way is listen to a good lecture in the class (T7).

One teacher perceived textbook reading and three thought extensive reading was useful for students, but they suggested the parents should read with their children to stimulate their interest in biology reading.

Many parents bought lots of biology relevant books, but they didn't read with the children. If parents only demanded their children read the books, the children might not be interested (T9).

Two teachers thought that students needed to seek and organise information, and then present it or hand in it in a written form. These were seen as helpful approaches for the reason that through the process, students were able to do independent study.

The teacher providing a question and the students searching for information then writing a report or giving a presentation is a useful way of learning. This is a necessary training for the students (T3).

A small number of teachers thought other approaches, such as *reading the textbook*, were useful to student learning.

Interestingly, about one third of the teachers believed that the students used *copying notes* and *consulting teachers* as learning approaches students using, but none indicated they were helpful. Comparing the teacher and the student perceptions of student learning approaches (see Tables 5.2.1 and 5.2.2), the similarities are that both them perceived *listening to lectures* was the main learning approach the students currently used and the most helpful student learning approaches were *reading biology-relevant books or magazines* and *listening to lectures*. The differences are:

- (1) doing experiments was the second most common student learning approaches they were using but this response was not on the teacher list; and,
- (2) oral reports was supposed to be one of the most helpful ways by the teachers, but was not mentioned by the students.

To recapitulate, the teachers believed that the main reasons the students took biology were for interest, future career and increasing entry options. They thought students who took biology for increasing entry options and had little interest in

learning biology would not have satisfied learning outcomes, rather they might influence the teacher's teaching and the learning of other students. It appears that with the pressure of entrance examination both the students and teachers believed that students used the approaches they did not think most helpful and they were unable to use the approaches they consider most helpful.

6.4 Teacher views of interactive teaching and open investigation

Teacher descriptions seemed to show that they were accustomed to teacher-centred teaching and closed experiments, although not all of them were satisfied with these. Their thoughts about interactive teaching and open investigation are examined in this section.

6.4.1 Views of interactive teaching

The teachers were asked about their perceptions of interactive teaching (teaching with students interacting within the social context and with the physical world). They did not propose any questions about the definition of interactive teaching and gave their responses as agree, disagree and conditionally agree.

Two teachers agreed with interactive teaching. Teacher T2 narrowed down the scope of interactive teaching to group presentation. In this it seemed there were no interactions between the teacher and the students, because the teacher said:

All I have to do is just give them some topics, and then the students will search for information and report their findings in the class (T2).

No discussion was mentioned. Whether the teacher really agreed with interactive teaching is questionable.

Teacher T8 had a wider definition and approved of whole class discussion. He suggested:

We should explain some theories or mechanisms to the students at the beginning of the teaching, and then provide them some questions to initiate a whole class discussion (T8).

Six teachers hesitated to try interactive teaching because they knew well it takes time, and they experienced pressure to cover the syllabus. Other reasons included both the teachers and students need to prepare out of class, but the students could

not afford the time and the teachers were inexperienced. Two of the six thought interactive teaching would destroy their schedule.

Teacher T4 was concerned the students would dominate the teaching, so he would not be able to teach as he wanted to. Teacher T6 suspected that all students would have similar responses; hence she thought there was no need for them to exchange their opinions. She declared if she allowed interaction between students, it consumed time and she might have problem with classroom management. In her words:

In a 40-student class, I can discuss topics with no more than five students and I reckon the opinions of the rest of the students are similar to these five. Allowing the students to exchange their views is risky. They may chat instead of discussing the topic I gave them (T6).

Teacher T7 worried about covering the syllabus, teachers lacking experience of conducting interactive teaching, and students being unable to afford time to prepare out of class. She stated:

The teaching will cause the teacher to fail in covering the syllabus and the teachers are inexperienced in the interactive teaching. It is going to be a challenge to teachers. As for the students, they might feel it is interesting and know how they learn, but they need to study hard to catch up with the syllabus after school (T7).

The teacher T10 required her students to prepare before the teaching, but her students did not reach her expectation; so she gave up this requirement.

I tried to do the teaching, but the students seemed to have no interest in participating. I reckoned that they needed to study many subjects, so they didn't have time to prepare. I saw some students always staying outside the discussion (T10).

It seemed that she did not consider students have prior knowledge and the problem was how she could elicit it rather than the students needed to prepare a set of knowledge for interactive teaching.

Four teachers considered interactive teaching was only viable under certain conditions. Teacher T9 insisted that unless her students were fully prepared in advance, she could not use the teaching approach. The other three considered that interactive teaching was only suitable for students who had sufficient background knowledge and for small classes. A representative comment was:

I can't control the time, so I don't think it's suitable for me to use the teaching. It might be suitable for gifted students, who are smart and more willing to speak in public (T12).

To summarize, the majority of teachers disagreed with interactive teaching. They considered the teaching was time consuming, required both teacher and student preparation, and that it was suitable for able students. Compared with student responses (see Sections 5.5), more students than teachers supported interactive teaching. Perhaps this was because the students had low satisfaction with the current lecture classes and would like a different teaching approach. The students who supported interactive teaching had the same worry as the teachers that they could not afford the time for preparation out of class because they needed time to study for tests.

6.4.2 Views of open investigations

The teacher responses to conducting open investigations were similar to their views of conducting interactive teaching. The majority of teachers disagreed or conditionally agreed, and only a minority agreed with the approaches.

Five teachers disagreed with open investigations for various reasons. They questioned whether students and teachers had the required competence, and saw investigations as time consuming. Those who doubted student competence conformed to the student view (see Section 5.7.1). For example, Teacher T1 sensed that even if she had the freedom to design experiments, her students might feel insecure in doing them. In her experience, students did not do their part and take the initiative, rather they relied on the teacher to a great extent. She said:

I am afraid that the students will argue I teach too little if I am allowed to decide what I am going to teach. They have insufficient knowledge and ability to solve problems and will not learn actively. They might feel the teaching will become their burden. (T1).

In relation to the time consumed, and doubts about student abilities, diligence and interests, Teacher T10 suggested students should do traditional experiments.

Although the students can learn a lot from more open investigation, I might feel exhausted for spending too much time on it. I don't think they have the ability or interest to do more open work... If they are not very diligent or smart, the traditional experiment is more suitable for them (T10).

In contrast, teacher T4 noted that even the teacher might be not competent to organise for students to conduct open investigations. She commented:

The students are unable to design an experiment. Also the teachers do not have sufficient abilities to conduct open-ended activities (T4).

Five teachers conditionally agreed with open investigations. They suggested that unless there were a small class with smart students, no time constraints, no entrance examination, and no need for teachers to design the activities, they would not try open investigations. Three of them argued that the indispensable factors for open investigations were a small class, sufficient time and gifted students. Teacher T11 explained:

I have taught two classes of gifted students. There are ten students in each class. Those students have two more hours of learning biology than the regular students. It's easier to do open work in these classes. I provide some questions to be hints to guide the students doing open work (T11).

Another teacher stated she would like to try open investigations if the UEE was taken away. In her words:

If there is not the pressure of the UEE, I would consider using this type of experiment, but it will be a challenge to me (T6).

Yet another teacher stated she would not try interactive teaching or open investigations, unless organised teaching instruction materials were provided. She commented:

I am not interested in interactive teaching or open investigation, because I don't want to spend time in designing them. If they have been designed already, I would like to try (T9).

Only two teachers reported little hesitation in conducting open investigation, although the openness of the investigation they suggested was limited. One stated:

I ask the students to propose a flow chart before each investigation. I never tell them how to do it (they can get the procedure from the laboratory manual). I might just offer them the title of the task and the equipment (T7).

According to the responses to the student questionnaire (see Section 5.7.1), around two thirds of the students would like to see more open investigations. In contrast, only two teachers (less than 20%) agreed with open investigations. The main reasons they disagreed were a lack of confidence about teacher and student competence and that investigations were time consuming. Large class size was

also seen as inappropriate for conducting open investigations. In short, the interview teachers were less supportive of interactive teaching and open investigation than the students.

6.5 Summary of teacher perceptions of biology teaching and learning

Taken together, there are several main themes in teacher views. Student passive learning attitudes and low learning motivation were said to lead to teacher difficulties in conducting teaching. Most teachers and students agreed that most of the learning responsibility is with the teacher which appeared to be the main reason teachers believed that they should be knowledgeable and prepare work for students to the extent they felt exhausted. Most teachers used a transmission way to teach and considered it the most useful. Teachers, like students, felt experiments were too closed and time too constrained. On the other hand, both teachers and students thought lectures were efficient and helpful in preparing students for tests. Teachers considered lectures were easy to prepare and thought experiments helped students practice manipulation; whereas students regarded the experiment classes as useful in preparing for tests.

Both teachers and students thought students take biology to increase their university entry options and for interest. Students taking biology for future careers was emphasized more by teachers. It was ranked middle on the student list. Teachers concluded that students taking biology for interest learned best while those who took biology to increase university entry options at the expense of interest did not learn well. Teachers believed the teaching in cram schools encouraged passive learning. Most believed students listened to lectures, copied notes and consulted a teacher as approaches to learn, which were also the approaches students said they currently used and thought would increase their marks. These were not the ways the teachers regarded as most helpful, except for listening to lectures. A transmission approach was thought by most teachers to be most frequently used and to be the most useful.

The majority of interviewed teachers were less supportive of interactive teaching and open investigation than the students. They disagreed with interactive teaching

because the teaching could be time consuming and required both teacher and student preparation but they could not afford the time, and considered it was only suitable for able students. They also hesitated to support the conduct of open experiments because of a lack of confidence about teacher and student competence, big class sizes and time constraints. Such a view might explain why much laboratory work is of a recipe-type in secondary science education in Taiwan.

Based on chapters 5 and 6, the broad picture that emerges is a teaching/learning environment:

- (1) dominated by a concern with gaining knowledge from lectures and textbooks for the purpose of gaining marks in examinations;
- (2) conspicuously lacking in purpose and status in the practical components; and,
- (3) somewhat inflexibly structured into lecture and experiment classes.

6.6 Argument and suggestions for changes to biology lessons

In the Taiwan senior high school biology curriculum, the objectives are to: *establish the views of modern life science to solve the problems encountered in daily life*; and *cultivate student interest in life science*. However, in reality the students used the learning approaches they most disliked in their current lecture classes and tried to get results as predicted by following teacher's instructions in their experiment classes. Both ways were seen as useful to cope with examinations but did not make them more interested in biology. Also, the teaching emphasized text recall and was generally irrelevant to daily life. Few opportunities were provided for solving problems. It seems teachers and students saw this teaching as problematic. It is not feasible for the curriculum designers to expect the common goals to be reached under this type of teaching. For these reasons, it was time to explore some changes in teaching and learning in biology. In this study, the researcher had the intention to devise an intervention to help the students have better learning rather than merely criticize the policy or leave the students continue as they were.

Some general principles for designing an intervention programme based on the student and teacher responses were to:

- (1) encourage student-teacher and student-student interaction to activate student interest and facilitate more genuine involvement to achieve meaningful learning;
- (2) shift the teacher's role towards that of a helper to facilitate student learning rather than being only a knowledge transmitter; to encourage students to take responsibility for their own learning rather than regarding themselves as empty vessels waiting to be filled; to encourage them to work out problems by discussion. That is, move the class towards being more student-centred.
- (3) accent both process and product. The intervention programme emphasizes 'how' the teacher will teach and the students will learn and 'what' the teacher will teach and the students will learn. Higher order thinking skills (reasoning and integrating) will be stressed in the intervention;
- (4) connect concepts in the textbook to the student lives through intervention tasks that emphasize real life application; and,
- (5) use assessment that avoids factual recall which would increase the student burden. Paper-and-pencil tests could be replaced by alternative forms of assessment. For example, assessing students by question-feedback and supplying prompt aid to improve their learning during classroom discourse. Assessment for learning during biology lessons could enhance student attainment; it is expected to be more efficient and accepted by the students than traditional written tests.

Chapter 7

Devising and implementing an integrated intervention: Interactive teaching and open investigation

7.1 Introduction

This chapter describes the design of a five-week (four hours per week) intervention which was devised to improve senior high school student learning in biology classes. The teaching of the twenty-hour Cell Biology intervention was divided between fourteen hours (70%) of lecture and six hours (30%) of experiment classes. Reasons for this departure from the traditional practice in Taiwan (90% lecture and 10% experiment classes) are discussed later.

The general principles for the design of the intervention (Section 7.2), the details of the intervention (Section 7.3), the teaching approaches used in the intervention (Section 7.4), the summary of the design of the intervention (Section 7.5) and the implementation of the intervention are elaborated (Section 7.6).

7.2 The principles for the intervention

Based on the perceptions of students and teachers concluded in chapters 5 and 6, typical biology classes in Taiwan could be described as a combination of transmission teaching and closed experiments. In these classes the teachers often felt exhausted, the students bored, and thinking was not encouraged (see Sections 5.4.3, 5.6.2 and 6.2). In contrast, a review of research revealed that exemplary biology/science programmes that utilize more interactive classroom strategies tend to produce more positive results (Bonnstetter, Penick, & Yager, 1983; Brunkhorst, 1992; Vargas-Gomez & Yager, 1987). Additionally, many research studies indicate that constructivist approaches can contribute to effective teaching and learning (Lord, 1997; Skamp, 1998), and can generate high student motivation and develop higher-order thinking skills.

The intervention design for this study falls within the constructivist paradigm. It focuses on building on student existing knowledge and the construction of meaning in a manner about education and learning that takes account of Taiwanese Chinese beliefs. The five principles devised for the intervention are discussed below.

Principle 1: Shifting the roles of the teacher and student

Based on constructivist views of learning, effective teaching and learning involves students actively constructing their own understandings with teacher assistance (see Section 3.2.1). The learner must be active and engaged in intellectual effort to achieve worthwhile learning. For the purpose of enabling the students to learn actively, they need to be given, and to accept, a degree of responsibility for their own learning. However, from the outcomes of Chapters 5 and 6, it was found that teachers in Taiwan are often in charge of student learning. They transmit a set of well-organised science knowledge in a didactic way to their students. Students tend to passively await their teacher instruction. A majority of the students believed their learning efficacy depended on the quality and scope of teacher teaching materials. They also thought that responsibility for their learning lay with teachers. These ideas are consistent with behaviourist views of learning as a process whereby students accumulate facts transmitted to them by the teacher. They are also consistent with Confucian-heritage cultural beliefs that it is the teacher who guarantees student learning not students themselves. In the intervention, the roles of both teacher and student will be shifted. A situation will be created so that students need to take more responsibility for their own learning. In the intervention, the teacher will fulfil her duty by helping students develop their thinking rather than doing the thinking for her students.

In the intervention, the students are viewed as active learners rather than passive receivers. It is designed so students take most learning responsibility in theory teaching classes and doing open investigations. They have to design their own investigations, make their own decisions, propose convincing interpretations, and justify and evaluate others' ideas to construct their own meaning (see Section 3.4.6). The teacher is not positioned as a transmitter or controller of his/her students but instead as a helper, assisting student knowledge construction. The

learning activities, conducted in the classroom and laboratory, were devised to challenge students and also to allow the teacher to offer prompt assistance to guide students to achieve meaningful learning. The goal is that students take responsibility for their learning, and the intervention will help them to develop a *genuine understanding of the content of modern biology and its impact on human life* (Ministry of Education of ROC, 2002c), which is the objective of the Grade 12 biology curriculum.

Principle 2: Encouraging student-teacher and student-student interactions

In regular classroom settings in Taiwan, teachers transmit information and do not expect contributions from students (Yang, 2002). Consequently, there is little opportunity for teachers to explore student understanding of the intended learning outcomes (see Section 6.3.2). Even though students might have good examination marks, this does not guarantee real understanding because teaching and learning may not resonate in the way the teacher intended. Without interactions, teachers have few clues about student conceptual development (see Section 3.4.2) and their motivation for learning (see Section 3.3.2). Conversely, students have no chance to exchange views with their teachers and classmates to construct their own meanings. In terms of Vygotsky's view of social learning, the extent to which the students can develop their potential is closely related to their interactions with teachers and peers. Therefore, the social environment which students encounter and interact within is crucial to their learning (see Section 3.2.1). The Taiwanese Chinese belief as to the importance of environment to facilitate student learning also supports a focus on the social environment. Teacher and student comments indicated that student-teacher and student-student interactions only occasionally occur in the current biology classes (see Sections 5.3.1 and 6.3.2).

In the intervention, therefore, both student-teacher and student-student interactions will be encouraged as a way of students exploring differences between and evaluating ideas. Open investigations will be used as these are an especially effective way of achieving this (Jones et al., 1992). Open means students have more autonomy in defining problems, choosing methods and arriving at solutions. This contrasts with closed experiments, in which the task, procedure and outcome are pre-determined. Students need more interactions and

negotiations to reach agreement in designing and making conclusions in open investigation. Without sufficient interaction, the students are unable to perform open investigations successfully (see Section 3.4.6).

Principle 3: Emphasizing learning processes as well as knowledge products

Currently, biological information and knowledge is accumulating at an incredible rate. Teachers cannot expect or be expected to teach all the facts that are known. On the contrary, the current suggestion is that it is important to assist students to develop their own abilities to use and apply concepts in a critical and analytical way (Allen & Stroup, 1993). Adding to the complexity, studies have found that it is not unusual for students to misunderstand and retain information they have successfully used to pass courses (Astin, 1985) and that they cannot connect what they have learned to real life (Tinto, 1987). This type of learning is merely the retrieval of stored knowledge from memory, which only provides a knowledge product rather than a learning process that builds on prior knowledge. As a result it does not create genuine understanding (see Section 3.2.1). The recommendation is that teachers should shift their emphasis to helping students to know how to learn. In terms of the student and teacher interviews, it seems the students lacked thinking, especially higher order thinking skills, such as analysis, synthesis and evaluation (see Sections 5.4.1, 5.6.1 and 6.2.3). The data also revealed that students need knowledge to prepare for current tests (for example, see Section 5-4-3). Their emphasis on earning mark was influenced by examination culture (see Section 2.2) and could not be ignored.

The intervention will therefore focus on both the ‘how’ of student learning, as well as the traditional ‘what’ of the knowledge to be gained. More emphasis will therefore be placed on developing student abilities in reasoning and thinking skills in both the theory teaching and the open investigations (see Section 3.4.7). This corresponds with the objective in the Grade 12 biology curriculum *to develop student abilities to conduct life science research* (Ministry of Education of ROC, 2002c). The teacher will provide sufficient chances as she can for the students to consider and make modifications to their ideas to create genuine understanding through engaging in thinking processes.

Principle 4: Promoting relevance to daily life

As discussed in Section 3.2.1, a concept remains abstract and is not fully understood without application. Therefore, Howe (1996) suggests teaching from everyday concepts. In the present study, the students had difficulty in achieving meaningful learning. Many students complained they found biology abstract and they could not apply the theories taught to new situations (see Section 5.4); also, laboratory work was said to be irrelevant to their daily life (See Section 5.6.2).

This intervention therefore attempts to integrate student everyday experiences with the scientific concepts they have learned in school by application activities. The purpose of these is to make the concepts more concrete so as to enhance the students' understanding. Examples include: the application activity in Lesson 2 to design a healthy meal for vitamin and mineral supplementation; and in Task 2: to decide which fruit is better for a person on a diet. Through these activities, the students are expected to apply their scientific knowledge to solve problems occurring in daily life. This corresponds with the common goal of the senior high school biology curriculum *to explore the basic knowledge of life science and establish the views of modern life science to solve the problems encountered in daily life* (Ministry of Education of ROC, 2002c)

Principle 5: Devising assessment for learning

In Taiwan, assessment is quite often narrow in that it is a quiz or semester examination focusing on factual recall with the purpose of grading students at secondary school level (Lin, 2000). A majority of the students viewed assessment as their top learning difficulty (see Section 5.4.1) and some considered there was a need for assessment for learning in their learning of biology (see Sections 5.4.1 and 5.7.5).

In the intervention, therefore, assessment for learning was adopted to improve student learning and to provide further direction in teaching and learning (see Section 3.4.5). The teacher aimed to assess students by ongoing question-feedback. Self-evaluation helps to develop their cognitive skills, such as thinking skills. These are also an indication of student learning for the teacher to assess. This type of assessment could point to student individual differences (e.g. prior learning

experience and learning capacities), which is consistent with Confucius' thought that teachers should teach based on student individual difference (see Section 2.2.1), and allow the teacher to provide them with assistance based on their needs.

In short, the five chief principles of the intervention aim to shift the roles of teacher and student, encourage student-teacher and student-student interactions, emphasise learning processes as well as knowledge products, link teaching content to daily life, and adopt assessment for learning. Evidence from the students themselves, their teacher, the international literature and the senior high school biology curriculum in Taiwan all support these principles as a basis for the intervention.

7.3 The details of the intervention

This section attempts to detail the differences between the traditional biology classes and the intervention, display the structure of the intervention and describe the content of the lessons and tasks.

7.3.1 Definition of the lessons and tasks in the intervention

The intervention arose from the context of the traditional biology classes where, teachers teach students a body of facts from biology textbooks with little intention to help students apply them in their daily life. At the end of each chapter in the text, there are usually a couple of experiments. These experiments are conducted by the students in the experiment classes. The lab manual usually starts with a statement of purpose, then illustrates the apparatus used and procedures to be followed, then ends with some short-answer questions. Making hypotheses before doing the experiments is not required. The lecture and experiment classes are teacher-centred.

The intervention was based on student and teacher responses reported in Chapters 5 and 6 and adopted some student suggestions from these chapters. It comprised lessons and tasks. These very roughly equate to the former lecture classes and experiment classes and were conducted in the classroom and laboratory respectively. Also, the total time of teaching hours is the same in the intervention

as in traditional teaching. However, there were five fundamental differences (Table 7.1). Firstly, the proportion of investigations (below 10% in traditional biology classes) was increased to around 30% in the intervention. Secondly, the pedagogy was significantly different in that the intervention was planned as student-centred with the teacher a helper. Thirdly, links between theory and practical biology were much stronger in the intervention. Fourthly, the traditional biology lecture classes emphasized factual recall, and the experiment classes focused on predetermined outcomes. However, the intervention was designed to stress genuine understanding and stimulate student thinking. Lastly, the traditional biology lecture classes cultivated the student lower-order thinking, and the experiment classes taught manipulating skills. In contrast, the intervention was planned to cultivate higher-order thinking and problem-solving.

	Traditional lecture classes	Intervention lessons	Traditional experiment classes	Intervention tasks
Teaching hours	18	14	2	6
Pedagogy	Transmission (teacher-centred)	Interactive (student-centred)	Recipe-type work (teacher-centred)	Open Investigation (student-centred)
Links between theory and practice	Seldom	Strongly linked	Seldom	Strongly linked
Knowledge products	Facts and concepts	Explaining & applying biological models	Predetermined outcomes	Procedural & contextual understanding
Learning process	Lower-order thinking	Higher-order thinking	Manipulating skills	Problem-solving abilities

Table 7.1: The differences between the traditional lecture and experiment classes and lesson and task in the intervention

7.3.2 The structure of the intervention

The intervention which comprised eight lessons and three investigative tasks emphasized both conceptual and procedural understanding (Table 7.2).

Lessons and tasks	Teaching hours	Main conceptual knowledge	Learning processes and activities
Lesson 1: Multi-cellular organisms, plant cells & animal cells	2	(1)	Lessons: 1. Initiating and focusing questions to drive student thinking and stimulate interest 2. Small-group discussion (students debate opinions, listen to others' thoughts, make adjustments and finally construct meaning from the interactions) 3. Spokesman presents group conclusion to the whole class 4. Whole-class discussion and decision-making 5. Application activity (connect what they have learned in the session to their real lives) Tasks: 1. The students have autonomy to define the problem, choose a method and arrive at solution. 2. Question and hints are provided 3. They make a plan after discussion and negotiation, distribute work and carry out the work. 4. During the process, they observe, modify, convince people by interpretation of evidence, and reach consensus.
Task 1: Observation of plant and animal cells	2		
Lesson 2: Water, minerals, & vitamins	2	(2)	
Lesson 3: Carbohydrate & lipids	2		
Task 2: Which one is better?	2		
Lesson 4: Proteins & nucleic acids	2		
Task 3: Enzyme activity of plant and animal tissue	2		
Lesson 5: Cell walls & membranes	2	(3)	
Lesson 6: The nucleolus, chloroplasts & mitochondria	2		
Lesson 7: Golgi bodies, endoplasmic reticulum, ribosome & lysosome	1		
Lesson 8: The cytoskeleton, vacuoles & microbodies	1		

Table 7.2: The time-line, teaching content, main concepts and processes of the intervention

- Key: (1) During the process of embryonic generation, the cells of multi-cells organisms undertake differentiation. After differentiation, the cell types are variable and have specific functions.
- (2) Protoplasm is the fundamental substance by which cells show a variety of life phenomenon.
- (3) The basic structures of a cell include cell membrane, cytoplasm and nucleolus. Inside the cytoplasm, there are many cell organelles.

To mitigate the weakness of the current lecture classes which were seen as monotonous to such an extent that students dozed during them (see Section 5.4.3), each intervention lesson was composed of questions intended to stimulate student thinking and feedback from the students, a small-group discussion about the teacher's questions, a closing whole-class discussion and an application activity. One or two questions were provided as assignments after each lesson to help the students integrate the concepts they learned, including e.g. *Ask your Mom to buy a fresh chicken. Compare it with the animal tissues we had mentioned in the biology class. Describe the tissues you seeing and not seeing.* In the application activity, the teacher designed a question to assist the student learning from the process of solving problems, including *Please look for someone's (your parents' or relatives' ...) cholesterol examination report. List the detail data (triacid-glycerol ester, high-density lipoprotein...) and check whether he/she has normal cholesterol. If it is abnormal, how can it be improved?* The teacher provided some websites and book lists, and then encouraged the students to exchange information resources to extend their search areas.

In traditional experiment classes, the task, method and answer, or two of the three, were usually given (see Section 5.7.1), but students perceived they could not obtain most of the learning outcomes they expected from doing these closed experiments (see Section 5.6.1). Therefore it is inappropriate to use them in intervention. Although the students desire to take more open laboratory work (see Section 5.7.1), the completely open work is too radical to them because they have no experience in doing open work yet. Thus, the intervention provided them with tasks and left the method and answer open. In that way, thoughtful involvement by the students was expected to take place during the investigations. Each task in the intervention was planned for two hours. Because the investigations were to be conducted two hours before lunch time, timing could be flexible depending on the student needs in that context. Throughout the open investigation, the researcher expected the students to develop scientific reasoning skills and social skills, such as convincing people by the interpretations of evidence. Time was allowed at the end of an investigation for a whole class discussion of the results. The aim of this was to make class decisions.

7.3.3 The lessons and tasks

The teaching emphasizes depth rather than breadth and it is all closely tied in with daily life. A theory class precedes investigation because in real scientific work theoretical speculation goes before experimentation (Hodson, 1992b). The status of the students participating in the intervention is very special for they are at Grade 12 level and will take a significant examination afterwards. For this reason, the intervention had to cover the syllabus and proceed on a school-determined schedule. Cell Biology was chosen as the teaching topic because it followed a school-assigned teaching schedule. The teaching content was not fully restricted to the text of textbooks. Any points relevant to the teaching topics were open to be proposed and discussed by the students. Tasks 1 and 3 follow the school-assigned teaching schedule, but the content of these tasks was adapted. Task 2 is not on the schedule. It was devised by the researcher to increase the student application opportunities.

The lesson plan includes initiating and focus questions, applications and assignments in each lesson; the task contains questions and hints. The content of the three tasks are illustrated in Figures 7.1, 7.2 and 7.3 respectively. The lesson plans and tasks are detailed below.

Lesson 1: Multi-cellular organisms, plant cells & animal cells

Initiating and focusing questions:

- (1) Could you give some cell analogues?
- (2) How has a single-celled organism evolved into a multi-celled organism?

Application:

In terms of the given graphic, point out the distribution of the plant tissues we have learned in the class.

Assignment:

Ask your Mom to buy a fresh chicken. Compare it with the animal tissues we had mentioned in the biology class. Describe the tissues you seeing and not seeing.

Task 1 is conducted after Lesson 1. In Lesson 1, the differentiation and classification of cells are discussed. In an attempt to connect the concept of cells with real cells, the students bring one living thing (no need for whole thing, could

be part of it) they are interested in, to observe. It is necessary for them to know how to deal with the objectives they would like to observe around them, decide what type of cell it belongs to (helping classification) and search for other information which might not show up on textbooks. Task 1 emerges from the above consideration. It is more open than the traditional task in the textbook because students need to decide what they want to observe, think out how to deal with the object they bring to the laboratory and interpret experimental findings.

Task 1: Observation of plant and animal cells

An observation activity can help the students learn the new rules of engagement and become accustomed to open-ended work. In the first task, the students planned as individuals. An emphasis was put on the ownership and openness of the task. The students were divided into groups and carried on diverse activity at the same period of time. Each group needed to observe a given object as shown in Fig 7.1 (except the one they had brought in) at a given time, and then they rotated to observing the next objective, until all items were studied.

Task 1: Observation of plant and animal cells

Observe the living thing you have brought and the following living things which are on the laboratory desk. There are; Elodea, epidermis of long-life flower's leaf, blood cells and paramecium. Draw and compare their similarities and differences.

Hint: (1) The adjustment of diaphragm and focus knob.
(2) The thickness of samples.

Figure 7.1: The content of student investigation of Task 1.

Lesson 2: Water, minerals, & vitamins

Initiating and focusing questions:

- (1) Could water be replaced with other liquids in an organism? Why?
- (2) Can you give some examples from your life (your relatives or friends...) to explain what will happen if there are no mineral salts in our body?
- (3) Vitamins do not provide energy; why we do need them?

- (4) Carnivores do not consume vegetable or fruits. Will they suffer from vitamin C deficiency?

Application:

In terms of the given table, design a healthy meal for yourself containing necessary vitamins and minerals.

Assignment:

Your math teacher is pregnant now, what nutrition do you think she needs especially? Why?

Lesson 3: Carbohydrates & lipids

Initiating and focusing questions:

- (1) What are the main forms (monosaccharide, oligosaccharide or polysaccharide) of carbohydrate resources in your breakfast? Point out what form they belong to?
- (2) What kind of oil is more suitable for our health?

Application:

Margarine is a kind of vegetable oil, but why does it look like solid instead of liquid? Please use the concept we have learned to explain it.

Assignment:

Please look for someone's (your parents' or relatives') cholesterol examination report. List the detail data (triacid-glycerol ester, high-density lipoprotein...) and check whether he/she has normal cholesterol. If it is abnormal, how can it be improved?

Task 2 is carried on after Lesson 3. One of the topics in Lesson 3 is carbohydrates. Students are familiar with sugar which belongs to carbohydrates and they care about calories very much for keeping a good figure. For this reason, they might be interested to know what foods contain more sugar that they need to avoid especially when on a diet. Consequently, Task 2 was generated.

Task 2: Which one is better?

Task 2: Which one is better?

Mary is on a diet so as to become thinner. In terms of that, which one of the following fruits do you think is better for her? Grapefruit, orange, tomato or watermelon? Please design an experiment to help Mary in making a better choice.

Information:

- (1) The ingredients of four fruits (see given table)
- (2) Benedict Solution reacts with reducing sugar (monosaccharide and polysaccharide which contain aldose or ketose and can react with Fehling's Solution), if present, to form a coloured precipitate. Benedict Solution, when mixed with sugar and heated in a water bath, will change colour from blue to green to yellow to reddish-orange, depending on the amount of sugar present in the sample.

Figure 7.2: The content of student investigation of Task 2 (adapted from Haigh (1998)).

The second investigation is a problem-solving activity which is closely related to life. The students need to judge what information is useful in terms of the given table. Then decide on their direction. There is ample equipment and material on the public desk. The students can ask for further asparagus from the teacher, if needed.

Lesson 4: Proteins & nucleic acids

Initiating and focusing questions:

- (1) Which chemical compounds are the same in most creatures and which are different (in an amoeba, a bamboo plant, a mouse, a bee...)?
- (2) What part of our body is constituted by protein? Are there any differences between animal and plant protein?

Application:

What foods are appropriate for the patients who have kidney failure, milk and egg or corn and bean?

Assignment:

The colour of a cut apple or potato exposed in the air will turn to dark brown. How can this be prevented? What is the mechanism?

Task 3 is conducted after Lesson 4. The students discuss proteins in Lesson 4 and know that one very important protein is enzymes. To understand how enzymes relate to our lives, where they exist and what factors affect their activity, Task 3 was generated.

Task 3: Enzyme activity of plant and animal tissues

The required equipment and material is the same as Task 2.

Task 3: Enzyme activity of plant and animal tissues

Information: An enzyme such as catalase (found in peroxisome of living cells) is a protein molecule. It is used for removing Hydrogen Peroxide (H_2O_2) from the cells. Hydrogen Peroxide is the poisonous by-product of metabolism generated by most living cells including human cells. But do not worry too much. Catalase of living cell can speed up the decomposition of Hydrogen Peroxide to water and gas. The amount of gas indicates the amount of catalase of the living material.

Find out: (1) What gas is produced when catalase is introduced into Hydrogen Peroxide?
(2) Which of the following living materials - pork livers, carrots, cucumbers and potatoes have the most catalase?
(3) Could I boil the living tissue to keep it for a longer time but not affect the activity of catalase? How can that be proved?

Hint: (1) Consider the amount of the living material which you use and the surface area of this which will react with catalase.
(2) Catalase decomposes H_2O_2 very fast. To avoid the gas given off, you could use syringes and Blue-Tak.

Figure 7.3: The content of student investigation of Task 3 (adapted from Haigh (1998)).

Lesson 5: Cell walls & membranes

Initiating and focusing questions:

- (1) What are the differences between a cell membrane and cellophane?
- (2) A cell is isolated by its membrane. How could the cell interact with outside circumstances?

Application:

Propose some applications of hypertonic, hypotonic and isotonic solution from your life.

Assignment:

In terms of what you have learned in Lesson 3, explain why certain wheat has cold-resistant ability in winter?

Lesson 6: The nucleolus, chloroplasts & mitochondria

Initiating and focusing questions:

- (1) What is the most important part in a cell? Why?
- (2) What do you know about chloroplasts and mitochondria (make a comparison of them)?

Application:

Tina could not conceive a child, so she went to see a doctor. The doctor found that some substances in the cytoplasm of her egg prevented fertilization. He suggested that she should have transplanted the nucleus of her egg, into another woman's egg which already had the nucleus removed. In that way, she could have her own baby. What is your opinion?

Assignment:

Please compare the differences between the cell membrane and cell nucleic membrane.

Lesson 7: Golgi bodies, endoplasmic reticulum, ribosome & lysosome

Initiating and focusing questions:

- (1) What kind of cells in your body is rich of Golgi body (nerve cells, liver cells, bone cells, skin cells, and muscle cells)? Why?
- (2) Please infer the process by which insulin is produced and secreted by cells?

Application:

When tadpoles turn into frogs, their tails disappear gradually. Please apply the concept we had learned to explain it.

Assignment:

Find some diseases which are caused by organelle deficiency.

Lesson 8: The cytoskeleton, vacuoles & microbodies

Initiating and focusing questions:

- (1) Could a cell move? Why?
- (2) Is a vacuole more important to animal or plant cells? Why? Divide your group into two (animal cells and plant cells) and debate.

Application:

Do a role play of cell division of your skin cells.

Assignment:

How cytoskeletons maintain the shape of a cell?

The above are the main activities in the lessons and tasks. In practice, in the lessons not all the questions need to be asked; they will be modified based on the teaching context. The new teaching style is quite different from the previous one and the students will not be provided with well-organised blackboard notes in theory teaching classes. For the purpose of assisting the students, the teacher will provide handouts with clear notes for them only before the examination.

7.3.4 Summary of the details of the intervention

To sum up, the intervention stresses conceptual and procedural understanding. Eight lessons and three tasks constitute the structure of the intervention. The students are expected to develop a genuine understanding of the concepts and process skills in learning biology. The three tasks were developed to illustrate the application of what the students learned from the lessons and to cultivate student problem-solving abilities.

7.4 The teaching approaches used in the intervention

Four approaches were employed in the interactive teaching and open-ended investigations. These were: questions to initiate and focus teaching and learning, Socratic teaching approaches, group work based on discussions, conclusions from whole class discussions and adopting assessment for learning approaches.

7.4.1 Questions to initiate and focus teaching and learning

Questioning has been found to be a cognitive strategy which can provide insight into student thinking and conceptual understanding (Brogan & Brogan, 1995). Probing questions can elicit student understandings of subject matter. Skilled questioning can engage students in thinking by feeding their curiosity and by using real life examples. This type of question contrasts with that in traditional classroom discourses where the teacher proposes questions, a student replies, and then the teacher evaluates the reply (Lemke, 1990; Edwards & Mercer, 1989). Research indicates the questions in this approach are frequently closed and the average waiting time for a response is no more than three seconds (Rowe, 1987). In teaching theories, the teacher intends to ask questions, about concepts and/or open questions about student opinions at the start of a lesson to find out what students know, to engage their attention and to prompt them into action. In the student investigations, questions and information will be provided for the students in student investigation plans to focus their observation (in Task 1) and more open investigative work (Tasks 2 and 3) to help them understand learning purposes and to accomplish what they need to do. In the present study questions are designed to engage students in thinking and discussion. The teacher will provide sufficient time as she can for the students to contemplate questions or to exchange their opinions.

Alongside this, during the intervention, students will be encouraged to raise their own questions and to connect biology concepts to their daily life through applications intended to activate their interest and achieve meaningful learning. In attempting to make the students feel secure, the teacher will communicate with the students in encouraging them to show a respectful attitude toward other student questions. The teacher herself will be respectful of student ideas.

7.4.2 Socratic teaching approaches

The Socratic teaching method is teaching by asking instead of telling. It focuses on a dialogical method to teach (Brogan & Brogan, 1995). Socratic dialogues occurring between teachers and students can engage students in thinking in ways that lead them to develop deep levels of understanding based on their prior knowledge. It can allow a teacher to diagnose student misconceptions as they are learning and permit students to construct their own understanding (see Section 3.4.3). Where possible, student-teacher conversations in the intervention will proceed in a Socratic way. The teacher will employ student questions to engage them in thinking based on their prior experience, and then help them find answers to the questions themselves.

7.4.3 Group work based on discussion

Previous research has suggested benefits from group work in biology and other science teaching subjects (see Section 3.4.4). It has indicated a discussion-based programme is effective in assisting students to construct better reasoning skills (Sprod, 1998). In this study, Taiwanese Grade 12 students considered they might get help from capable classmates. Even if their classmates had less knowledge than their teacher, peer explanations could be easier to understand and more acceptable than the teacher's (see Section 5.3.1). Based on the recommendation of past research, and at the suggestion of the students, group work based on discussion will be adopted as a strategy in the intervention.

In both the theory class and the open investigations of the intervention, the students will be separated into small groups of five or six. There will be a spokesman representing each group and he/she will present the conclusions from his/her group to the whole class. When a spokesman goes to the front and presents group data, the teacher will sit amongst the students, some way back, to symbolise the provisional relinquishment of leadership.

It will be made clear that all group members have an obligation to share the work load and responsibility. Particularly, in the investigation aspect of the intervention, each group member will be assigned a role in performing the investigation (see Section 3.4.4). During the process, students will need to work out solutions to

questions by communicating, negotiating and judging, and then reaching agreement. Through cooperation, students will each make their own contributions, which can compensate for any deficiency in their individual ideas and make the performance of investigations better.

7.4.4 Conclusions from whole class discussion

The teacher has no intention to dominate the classroom conversation, but rather to coordinate taking turns and provide prompt guidance when the students need it. In this context, the teacher will use questions to guide discussions. When group spokesmen present their outcomes of discussion from theory classes or investigations, their contributions will not be judged by the teacher immediately, but left hanging, as an invitation to others to give their support or objection. This is because the purpose is not to end the class as soon as possible, but rather to provide the whole class an opportunity to re-consider the question and evaluate different thinking. Conclusions will be drawn with due regard given to the scientific view or the whole class's decision.

7.4.5 Adopting assessment for learning approaches

In this study, there is a variety of assessment for learning. During the lesson or task, on-the-spot feedback depending on student understanding will be provided by the teacher to promote student learning. An assignment based on each lesson and self-evaluation for each task will be offered to the students and comments will help in clarifying their concepts. Group presentation and laboratory reports are also assessed. Some traditional assessment will remain: two written question-answer form assessments about cell biology, administered pre- and post-intervention.

7.5 Summary of the design of the intervention

The intervention has been developed to have the following characteristics: a shift in the roles of teacher and student; greater student-teacher and student-student interaction; an emphasis on the learning processes as well as knowledge products; a linking of content to daily life; and, the adoption of assessment for learning activities. The intervention consists of eight lessons to do with cell biology and

three tasks to apply what the students have learned from the lessons and to cultivate student abilities in problem-solving. The intervention teaching approaches include using questions to initiate and focus teaching, using Socratic teaching approaches, group work based on discussions, whole class discussion to develop a collective conclusion and adopting a variety of assessment for learning.

7.6 The implementation of the intervention

Before the commencement of the intervention, the researcher explained to the students how the intervention, including the interacting teaching and open investigations, would be conducted. The information about the intervention the students were informed is described below.

Most of the planned teaching activities in the intervention involved group discussions, and they would be grouped for the discussions. The grouping was based on their seat numbers with six students in most groups. In open investigations, one group of eight students in Room 25 insisted on working together, consequently the grouping of other groups in Room 25 were also based on their preferences. During the discussions the students were expected to respect others' ideas. The teacher would also show this attitude during the teaching. She explained she would be audiotaping the classroom conversations and conducting student interviews. The students would need to fill out questionnaire for research purposes; these were to have no relevance to their grades. There would be no quizzes during the intervention. The students would be graded through the term examination, assignments in theory classes, and work sheets and a written report for each investigation. Although the teacher used assessment for learning, it was for determining next teaching steps and enhancing student learning. Therefore, there was no need to explain this to the students.

The teaching hours in the theory classes were as usual. The teacher would not provide a long lecture for the classes, rather she would make use of questions to initiate group discussions and give a 10-15 minute lecture, if it is necessary. Group representatives needed to present their negotiated conclusions and debate for them in a whole class discussion.

In the open investigations, there was a two-hour session for each task. Students were allowed to continue their investigations if this session was followed by a lunch break. Students were not provided with specific instructions on what to do for the investigations. The teacher provided some hints and prompt questions on the student planning sheet to help them. They needed to make decision after group discussions. At the end of each investigation, a whole class discussion would help them to make final conclusions. The student evaluation-sheet helped them to evaluate their own learning. Two of the tasks followed the lab manual with modifications and one task was original, but conducted in investigative way.

During the 20-hour intervention, some students approached the teacher and expressed their enthusiasm, especially at the end of an investigation where some students had finished earlier. The casual talks enabled the teacher to understand how students perceived the intervention and their opinions provided clues for her to make adjustments in her actions. For example, some students suggested that when the teacher circulated the groups, she needed to approach group representatives (they took turns for this role) to see whether they had a problem because some students were timid and might not ask for help. Students might be cheerful, excited, upset or worried during the intervention. The teacher needed to observe their responses and comfort or encourage them.

The teacher listened to the tapes of lesson dialogues and student interviews and then reflected on her own teaching every night. This helped to enhance her teaching. The reflections enabled her to notice the teaching pace, enhance her questioning skills and modify focus questions based on student responses. The classroom context was more dynamic than previous biology classes, therefore it required the teacher to reflect frequently so as to help the students achieve better learning.

This chapter has described the design and implementation of the intervention. The evaluations of student learning in the interactive teaching classes and open investigations are presented in Chapter 8 and Chapter 9 respectively.

Chapter 8

Evaluating the interactive teaching

Traditional teaching gives us facts, which the editors of textbooks might not be sure of either, to memorise. If those facts are found not true, we will feel hard to accept this. Because we have spent much time establishing the concepts in our mind, it is not easy to change it. The new teaching, which enhances our thinking, though provides possible explanations, enables us more easily to modify our concepts (S2313).

8.1 Introduction

This chapter reports on the evaluation of the interactive teaching. The five guiding principles generated in Section 7.2 were applied to the intervention. They are: shifting the roles of teacher and student; encouraging student-teacher and student-student interactions; emphasising both knowledge and the learning process; linking teaching content to daily life; and, adopting assessment for learning.

The assumptions behind the inclusion of interactive teaching in the intervention are that it will promote student learning biology concepts and develop their ability to reason and think. In this chapter, qualitative data from student interview SI 2 (see Appendix 4) and the classroom dialogues of lessons and quantitative data from Tsai's Pomeroy Questionnaire (see Appendix 7), Questionnaire 2A1 and 2A2 (see Appendix 9) and Pre- and Post-test (see Appendix 14) are presented. As will be argued below, the outcomes of qualitative and quantitative data provide evidence in support of these assumptions. Seventy-three Grade 12 students attended the intervention programme (195 students were in the control group) in the fall of 2001. Their backgrounds are detailed in Section 4.4.

There are five aspects which illuminate the key features of the interactive teaching aspect of the intervention. Evidence of student learning in the interactive teaching classes is shown in Section 8.2. Student perceptions of the interactive teaching classes are revealed in Section 8.3. A comparison of student responses to the interactive teaching classes and traditional lecture classes is described in Section 8.4. The change of student scientific epistemological views (SEVs) and the relationship between student SEVs and their views of learning and their thoughts about the interactive teaching are discussed in Section 8.5. Lastly, the traditional and intervention student test achievements are compared in Section 8.6. The

evaluations of student learning in the interactive teaching classes are summarized in Section 8.7.

8.2 Evidence of student learning in the interactive teaching classes

Restricted to the school context, the intervention covered the syllabus for Grade 12 Biology that was supposed to be taught before the first term examination in the fall of semester 2001. The main teaching content was cell biology. This section focuses on student learning processes and outcomes for cell biology. Dialogues are presented under different headings but it needs to be noted that there is often more than one element in case. For example, most of the classroom dialogues that involved a Socratic approach, also involved assessment for learning and co-construction of meanings. Here, the dialogues provide evidence that the students constructed knowledge in social contexts, changed their concepts, engaged in deeper thinking and reflected on ideas through Socratic teaching approaches. They clarified their concepts and constructed their knowledge through group work and improved learning through teacher assessment for learning.

8.2.1 Students constructed knowledge in social contexts

The following dialogues highlight how the students constructed meaning by thinking through ideas and also by linking ideas to everyday experience. The teaching was student-centred so students took more responsibility, which is emphasized in Principle 1. The teacher's intention was to make concepts more concrete in line with Principle 4 in the intervention design.

Students constructed knowledge by thinking through ideas together

The dialogue provides evidence that through teacher-student discussion and negotiation the students generated possible/acceptable interpretations and constructed more scientifically accepted knowledge with teacher guidance. The students discussed whether carnivores can suffer from Vitamin C deficiencies during the 2nd Lesson (see Section 7.3.3) when, in order to stimulate the student thinking and initiate discussion; the teacher posed the question: *Carnivores do not consume vegetable or fruits. Will they suffer from vitamin C deficiency?* The students did not think that carnivores would suffer from vitamin C deficiency. They gave many possible reasons for this, some were:

- S2513: *When the carnivore eats the herbivore, there are lots of grasses waiting to be digested in the stomach of the herbivore. The carnivore takes vitamin C from the grasses not completely digested.*
- S2503: *I think in the body of herbivores there is sufficient vitamin C for the carnivore.*
- S2516: *Is it possible that the carnivore could produce vitamin C rather than obtain it from food?*
- S2514: *Perhaps the carnivore eats vegetables or fruits secretly, but we do not know. (Laughing)*

The teacher used a series of questions to guide the students towards a more scientific understanding. She initiated the following dialogue to help S2503 think through her idea.

- T: *After taking vitamin C, where does it go?*
- S2514: *It is peed by us (Laughing).*
- T: *The purpose you take it is to pee it?*
- S2516: *No. It is peed by us if it is too much.*
- T: *What does that mean?*
- S2516: *Well, it isn't stored in our bodies. We need to re-ingest it after a period of time.*
- T: *According to that, do you think there is sufficient vitamin C left in a herbivore's body when a carnivore eats a herbivore?*
- S2503: *It seems not, because herbivores don't have surplus vitamin C.*

She asked S2513 if he thought carnivores eat vegetables, and initiated the following dialogue:

- T: *Do you think carnivores eat vegetables?*
- S2513: *No, they don't.*
- T: *If they don't eat vegetables, will they be able to digest the vegetables which are left in the herbivore's stomach?*
- S: *That sounds unreasonable. (in a soft voice, the student could not be identified)*

Consequent to student S2516's suggestion that a carnivore could produce vitamin C rather than obtain it from food, a conversation proceeded:

- T: *Why do you think carnivores produce vitamin C by themselves?*
- S2516: *I just reckoned.*
- S2537: *I think it is because of natural selection.*
- T: *Could you explain that more clearly?*
- S2537: *Originally, all the carnivores were unable to produce vitamin C. Gradually, due to gene mutation or recombination, the ones with the ability to produce vitamin C were more likely to be successful than the others.*
- T: *What do you think about what we have discussed?*
- S2516: *Which one is correct...? Tell us the right answer.*
- T: *So far, the scientists are in closer agreement with to S2516's view on the matter.*

In this case, student S2537 provided an explanation for S2516's suggestion, one that was consistent with usual scientific thinking.

However, in the following student interview and survey, some of the students complained the teacher had not provided them with an absolute answer. They were not satisfied with the teacher summation that scientists' views were similar to student S2516. They thought she should here deny the other interpretations strongly and directly.

Students constructed knowledge by linking ideas to everyday life

In this second illustrative dialogue (also from Lesson 2), the teacher asked students to provide some everyday examples of vitamins and minerals. Her intention was to help them realise the function and importance of vitamins and minerals in their lives. A student gave the example of her mother needing iron because she was anaemic.

S2526: My mum was anaemic, so the doctor said that she should take iron pills everyday.

T: Look at the structure of hemoglobins. Do you know why an anaemic patient needs iron?

S2526: The heme of hemoglobins contains an iron ion.

S2530: Oxygen binds with the iron ion.

S2515: Without iron t hemoglobins will lose the function of carrying on oxygen.

Another talked about her grandmother needing calcium because she had osteoporosis.

S2524: My grandma had osteoporosis and the doctor suggested her to take calcium pills.

T: Do you know the reason she got the disease?

S2524: She can't absorb calcium efficiently.

T: So do you think it is feasible by taking more calcium pills to increase the level of blood calcium?

S2531: No, we need to find the possible reasons first.

T: What will be the main reason?

S2529: She is too old and lacks estrogens. She had better take estrogens and calcium at the same time to prevent against calcium loss.

S2506: Will most women who go through menopause get osteoporosis?

T: Not really. It depends on how much calcium storage they have in their bones originally

These vitamin/mineral deficiencies occur frequently in women, and calcium deficiencies especially are seen in menopause. Other students said their families had the same experiences.

Another example relevant to daily life occurred when a student introduced a commercial advertisement on TV:

S2511: There is milk powder being advertised that contains added Vitamin D. A man poured milk into a cup with a base full of pores and said 'In that way, you will lose lots of calcium in milk. I suggest you supply vitamin D to retain the calcium. Our milk powder supplies sufficient vitamin D, which is your best choice.' It sounds reasonable, should we purchase it?

T: Can we produce vitamin D by ourselves?

S2511: Yes, but only if we have sufficient sunshine.

T: You will produce enough vitamin D if you have sunshine for half of an hour 2-3 times weekly. You can decide whether you need to purchase the milk powder in light of your own situation.

S2511: I think sunshine is natural and cheaper than buying milk powder.

People require the ability to judge what is important in their daily life regardless of their career choice in the future. In the above example, the students demonstrated they could use their existing knowledge to make a judgment.

Evidence is provided that students could construct their own knowledge through interactions with the teacher, peers, and their physical world in the social context provided by the intervention classes. It also illustrates that students were able to link what they were learning with their daily life indicating vitamins/minerals were not abstract to them. This is consistent with the common goal for the senior high school biology curriculum standards *to explore the basic knowledge of the life science and establish a view of the modern life sciences so as to be able to solve the problems encountered in daily life.*

8.2.2 Students changed concepts

This section highlights that student concepts were changed through teacher use of questions to stimulate cognitive conflict. This process involved the teacher eliciting and then challenging student ideas.

Student alternative conceptions uncovered

In Lesson 7, the teacher asked *please suggest the process by which insulin is produced and secreted by cells*. Her intention was to determine how much they knew about the relationship between gene and protein synthesis, and transportation of proteins and how proteins are secreted. It was also intended to help the students connect these concepts to what they had already learned. The following statements were the group conclusions of five groups in Room 23, as shown on the blackboard. They were:

- Group 1: (*Didn't outline their conclusions.*)
- Group 2: *DNA (transcript) → RNA (translate) → raw protein → Golgi body (processing) → insulin (enzyme)*
- Group 3: *DNA (transcript) → RNA (translate) → (tRNA bring amino acids →) protein (transport to) → REM → Golgi body → cyst → insulin → secreted through membrane*
- Group 4: *DNA (transcript) → RNA (translate) → protein (on REM) → exocytosis*
- Group 5: *Ribosome on rough endoplasmic reticulum (REM) → accumulating raw material → synthesizing protein → SEM → forming cyst → Golgi body (processing) → insulin (hormone) → exocytosis*

Students in Groups 2, 3 and 4 apparently were able to apply the concept that DNA carries the genetic information which is transcribed to RNA and subsequently translated to protein appropriately.

Group 5's answer revealed an alternative conception. They thought that protein is synthesized on the REM (Rough Endoplasmic Reticulum: an organelle of a cell, its function is protein synthesis) and then transported to the SEM (Smooth Endoplasmic Reticulum: an organelle of a cell, its function is lipid synthesis). In other words, they thought protein will pass through both the REM and SEM before leaving the cell. They did not recognize the real function of SEM. Another alternative conception that *insulin is a type of enzyme* was raised by the Group 2 students. They were confused between the enzyme and the hormone, because the students said the pronunciation of the Chinese translations are very similar (chiao su and ji su) and both were abstract to them.

Student concepts challenged and changed

Taking the second alternative conception as an example; a discussion about the differences between enzymes and insulin was initiated by the teacher. The intervention was to help students clarify their ideas and prompt conceptual change.

T: What is an enzyme?

S2516: An enzyme is a type of reactant, which accelerates reactions. Insulin is a reactant, so it is enzyme.

T: Do you guys think so?

S2530: No, an enzyme is a catalyst but not a reactant. Insulin is not a catalyst.

T: What is the function of insulin?

S2516: It turns blood sugar into glycogen.

T: Let me show you the mechanism by which insulin binds the target cell and induces the activation of proteins.

T: Please show me the mechanism by which an enzyme reacts with its substrate.

S2513: (doing a sketch of the mechanism)

T: What do you think?

S2516: Their mechanisms are totally different. Yeah, insulin does not belong to enzyme.

In this example, a student outlined the mechanism of an enzyme and compared it with the teacher's explanation of the mechanism of insulin. The students constructed the correct concept that insulin is a type of hormone to replace the old concept that insulin is a type of enzyme. Based on S2516's response, conceptual change had occurred. This conforms to the objective in Grade 12 in senior high school biology curriculum *to explore the basic principles of life from molecule and cell levels*.

8.2.3 Students thought more deeply and reflected on ideas through a Socratic teaching approach

In the intervention, the main teaching approach was the Socratic approach (see Section 3.4.3). This approach encourages interactions between the teacher and students to engage students in deeper thinking in a manner consistent with Principles 2 and 3 in the intervention design. However, certain students might feel uncomfortable by aggressive questioning if the teacher did not explain to them. Therefore, before the commencement of teaching, the students were told that the teacher would propose questions rather than provide answers to help ensure they were not worried unnecessarily by this new approach.

Students clarified concepts through teacher questions

In Lesson 6, a comparison of chloroplasts and mitochondria was made to help students clarify these two concepts. These two are cell organelles; both have double membranes and are able to produce ATP. The students often confused the two organelles because of their common attributes. One idea raised by a student was about the division reproduction of these two cell organelles.

T: What are the differences between mitochondrias and chloroplasts?

S2318: Mitochondria can divide but chloroplasts can't.

T: Why do you think so?

S2318: In terms of the description on the textbook page 49, it says mitochondria can divide, but doesn't mention that the chloroplasts can divide.

The teacher did not immediate provide the answer, rather she used another question to help him think further.

T: Do you think chloroplasts have a limited number when a young leaf grows to a mature leaf?

S2318: No, they will increase along with the leaf, because the latter one is bigger and greener than the former one.

T: How does a normal cell increase its amount?

S2318: Through dividing. But a chloroplast is an organelle rather than a cell.

Again this student did not know how to continue his thinking. The teacher used another question to stimulate him. Finally, he attained the desired knowledge.

T: What is the essential factor a divided cell needs to have?

S2318: DNA. The cell can divide if it has DNA.

T: Do chloroplasts have DNA?

S2318: They do. Oh, so they can divide!

This example is but one of many such examples that indicated that the students could think deeply and reflect on their own ideas, in response to teacher questioning that encouraged them to clarify their concepts and construct knowledge. Other examples of the value of this approach arose during discussion of *Could water be replaced with other liquids in an organism? Why?* (Lesson 2), *What type of oil is more suitable for our health?* (Lesson 3) and *What kind of cells in your body is rich of Golgi body (nerve cells, liver cells, bone cells, skin cells, and muscle cells)? Why?* (Lesson 7). The teacher personally very much appreciated this teaching strategy; however, it was time consuming. This is congruent to the objective in Grade 11 senior high school biology curriculum *to develop the abilities of reasoning*.

8.2.4 Students constructed knowledge through group work

At the beginning of the intervention the students raised their own idea with little confidence. However over the course of the unit they became more confident in offering ideas and debating them to find an answer through the support of the teacher and in cooperation with their peers. When a student suggested a possibility, if this did not convince the teacher and other students, another student would offer another idea. Students working in groups put forward opinions, debated these, and finally reached a consensus. Through many student contributions knowledge was constructed.

In Lesson 3, for example, the students were asked what kind of carbohydrate they liked for breakfast. They discussed this in groups. The teacher approached one group and participated in an interesting group discussion. One student challenged

another student's argument that taro contains no other carbohydrate except starch because taro is not sweet at all. The teacher then probed to find out if students knew how to test whether taro contains sugar.

T: What reagent do you think we need to add for a sugar test?

S2536: Saliva.

In Grade 7, all students do an investigation in which they mix saliva with starch solution and test for sugar. Often they only remember the saliva and starch solution being together but forget the reagent test for sugar. It is likely student 2536 replied without thinking. When the teacher prompted for deeper thinking the students were able to clarify their ideas.

T: What will happen if we add saliva?

S2535: Saliva is going to hydrolyse the starch into sugar.

T: So, you add saliva and get positive reaction of sugar to verify that taro contains sugar?

Other students raised different opinions and debated these.

S2537: No! No! No! We can't add saliva. We should add BTB reagent.

T: Does BTB test for glucose?

S2535: No, BTB test for CO₂.

T: Does BTB test for CO₂?

S2539: Lime solution tests for CO₂.

S2538: BTB tests the pH value of a solution...

The students continually tried to match the chemical tests they knew about with the reagent needed for testing for sugar.

S2535: Probably phenol blue.

T: What is that for?

S2537: To test the pH of a solution.

S2539: It must be Benedict's solution.

S: Yeah, yeah (students echoed and clapped).

Eventually a student put forward the correct reagent and the group agreed it was appropriate. This case shows students in a group, each making a contribution to the discussion. Together, the students constructed the correct knowledge. Other examples were in the discussions of *What part of our body is constituted by protein?* (Lesson 4) and *Is a vacuole more important to animal or plant cells? Why? Divide your group into two (animal cells and plant cells) and debate* (Lesson 8). The teacher observed that students were generally very focused during such debates and a majority of the students contributed to the discussions.

8.2.5 Students improved learning through teacher assessment for learning

Students improved their learning through teacher assessment for learning in the context of class discussions. In a way this is congruent with Principle 5 of intervention design.

The following dialogue shows a discussion about the DNA in different cells of an individual (Lesson 1). Students clarified concepts through question-feedback from the teacher. The dialogue was:

- T: Does every cell have the same genes in our body?*
S2310: Maybe not.
S2315: It does. The cells in one individual have the same DNA.
T: But how can you make sure the cells in one individual have the same DNA?
S2319: They come from the same fertilized egg.

When the following teacher's question was raised, students demonstrated their greater understanding in the concept that cells have the same genes but different shapes. The dialogue was:

- T: Could you tell me why they have the same genes but different shapes?*
S2305: There are only some genes of a cell are activated and produce protein. Different genes in different cells are activated, which makes them have different shapes gradually.
S2321: That is affected by the stimulation of outside circumstances.

In this context, student conceptual development was facilitated through the teacher's question-feedback. Some students may not have clear ideas because there were many opinions. Through the teacher using the student language and questioning them, they could grasp the key points of this lesson.

- T: Let me put your words together for you. Different external stimuli activate genes to produce particular proteins, which causes the cell shape to change and therefore have a specific function. The change of cell shape is for carrying out a specific function. What else?*
S2335: The cells which survive have certain shapes because they are selected by the environment.
T: So, you think that natural selection preserves the cells whose shapes are helpful for adapting their environment.
S2335: Yes. The more the cell shape can match the cell function, the stronger the possibility to survive.

Students improved learning through the teacher's questions. To make sure the students knew that cell shape was tightly related to its function, the teacher asked:

- T: What is the advantage that a nerve cell has with the shape of branches?*

The following quote demonstrated that students had real comprehension about the relevance of cell shape and function.

S2328: It is helpful to transmit information. If it had a round shape, the information wouldn't go far.

This made it obvious that student concepts were clarified and developed through teacher assessment for learning approaches. Other examples could be seen in the teacher-students dialogues of *Vitamins do not provide energy; why we do need them?* (Lesson 2), *What are the differences between a cell membrane and cellophane?* (Lesson 5) and *What is the most important part in a cell? Why?* (Lesson 6).

8.2.6 Summary of student experiences of learning in the interactive teaching classes

Students were helped to reflect on their own ideas through Socratic teaching approaches. Through classroom interactions they raised their opinions, debated these and reached consensus to construct meaning and understand biological concepts. Students could evenly make contributions to the group in constructing knowledge. Also, through teacher's question-feedback, student alternative conceptions were uncovered and challenged. The clarification of these alternative conceptions led to conceptual change. Classroom conversations stimulated student interest to connect their concepts to daily life. All these experiences facilitated student learning in a way that is consistent with the five principles for the design of the intervention and the senior high school biology curriculum in Taiwan.

8.3 Student perceptions of the interactive teaching classes

At the end of the interactive teaching, 23 students from the intervention classes were interviewed to elicit their thoughts about the teaching. Their responses were sorted into three aspects; their perceptions of learning and of teaching in the interactive teaching classes, and suggestions for enhancing the interactive teaching.

8.3.1 Perceptions of learning

The students were asked their thoughts about their learning in the interactive teaching and what they learned from peer discussions.

Thoughts about learning in the interactive teaching

Student perspectives about how the teaching influenced their learning are categorized as shown in Table 8.1 and are described in more detail in the following paragraphs.

Thoughts about learning in the interactive teaching	Percentage (%) (N=23)
The importance of prior knowledge	56
Active learning	44
Thoughtful learning strategies	35
More meaningful learning	13
A need for preparation in advance	13
Learning from peers	9
Increasing confidence	9
No absolute answers	4

Table 8.1: Student perceptions of learning in the interactive teaching classes

Thirteen students (56%) declared they found that prior knowledge was indispensable in facilitating their learning in the interactive teaching. Without this, they had problems participating in discussions. As one of them explained:

Our previous knowledge can be a basis of discussion. However, I have little previous knowledge because I did not learn well in Grade 11, so I am not sure of certain interpretations in discussions (S2502).

Ten students (44%) realised they needed to take more responsibility for their own learning and learn actively. They pointed out that students who attempted to memorize without understanding or put responsibility on their team mates were not well placed to adopt the new teaching. As one capable student commented, in frustration:

This teaching is suitable for the students who take the initiative in learning. A couple of my group members were inattentive and they often said to me 'what you think is sufficient for our group presentation, because you are so smart.' They thought that I needed to take the responsibility for presentations, because my marks are higher than theirs. They discuss only when the teacher approaches them. They learn passively (S2336).

It was clear that students perceived a need for learning actively. One student explained this in relation to teacher questioning as follows:

The teacher waited for the students to reply. If the student doesn't know how to respond, the teacher will use other questions to help the student (S2504).

Eight students (35%) realised they needed to adopt thinking as learning strategy to match the new teaching. They were invigorated by the need to think more deeply. For example:

The current class brings a change for us - from seldom thinking to thinking very often. We feel more energy-taking than before, because we need to use our brains very often (S2305).

Obviously, the students considered the new teaching approach created opportunities for them to think rather than passively receive knowledge.

Three students (13%) declared they were surer about what they had learned and the reasons they learned, and thus had real comprehension. They admitted they had taken memorizations as a learning strategy for granted in traditional teaching. However, in the new teaching, they could not follow the textbook blindly. From the following quotes, we can see they now valued comprehension more than memorizing:

We don't take ready-made knowledge from the textbook any more. We know where it comes from and what for (S2504).

In the previous teaching, the teacher demanded that we copy notes. But I now feel that understanding what the teacher said in the class is more important than copying notes (S2535).

Three students (13%) also noted that the teacher needed to prepare questions and they needed to search for review relevant information to improve their learning efficiency. For example:

Without preparing before the class or reviewing after school, I can't catch up with my classmates in the next class. If I can catch up with them and I attend the discussion, I will learn very much (S2304).

The options *learning from peers, increasing confidence* and *no absolute answers* were mentioned by one or two students and these are not discussed here.

Thoughts about learning from peer discussions in the interactive teaching

The major activities of the interactive teaching were group and whole class discussion so what students perceived they had learned from peer discussions was

explored. Their responses were categorized into four aspects: discussions could uncover alternative conceptions, help them appreciate different views, promote learning, and enhance competence in skills.

Eight students (35%) found that they identified their own alternative conceptions through discussions. Something they took for granted before the teaching might be revealed through peer discussions as incorrect. One stated:

I suddenly realise through discussion that's not like what I supposed it to be (S2318).

The new teaching created opportunities to identify their alternative conceptions, and they were aware this may not have happened in previous teaching. One said:

From peer discussion I found some of my concepts are wrong. If those concepts don't appear in the test, I may have never realised that (S2336).

Seven students (30%) said they no longer judged peer opinions as either right or wrong but rather they appreciated their different interpretations. They recognized that understanding peers' thoughts broadened their own thinking. As one student explained:

Understanding others' thoughts and the differences between theirs and mine, make me feel learning much (S2507).

Another reiterated this point:

When I considered matters from my classmates' positions, I found a different world (S2327).

Seven students (30%) indicated that peers promoted their learning. Very often, the students were surprised by their classmates' ideas and on occasion acquired new inspiration through those ideas. The opinions their peers raised frequently reminded them to think more deeply. For example:

My group members are very smart and they often provide many ideas. Their thinking paths are totally different from mine. They often propose what I have never thought before, which reminds me that I need to consider more details (S2330).

Based on these reasons, the students conceived that some peers were more mentally nimble than them, therefore, through discussion their peers could challenge them to think more deeply.

Six students (26%) declared that they had developed better competence with presentation, debate, negotiation of ideas and making judgements, all discussions that required them to be actively engaged in thinking. Through interactions, they learned to negotiate with group members and make appropriate judgements. For example:

I learn how to reach a compromise with group members by negotiation. Experiences and knowledge can help me to convince others and reach agreement. I have confidence in debating (S2534).

To conclude, students sensed the importance of prior knowledge in constructing new knowledge as a consequence of the interactive teaching. They realised they needed to adopt thinking as a learning strategy and learn actively to reach meaningful learning. They experienced benefits from peer discussions. Their statements about their learning from discussions suggested many of the students had moved towards a more constructivist approach to learning where they were actively comparing, contrasting and revising their ideas as a consequence of social interaction with the teacher and their peers.

8.3.2 Student perceptions of teaching

In this section, student perceptions of the features of the interactive teaching, ideas about the strengths and weakness of the interactive teaching classes and suggestions for enhancing interactive teaching are set out.

The features of the interactive teaching

Students proposed seven features of the interactive teaching, which echoed the five principles of intervention design (see Section 7.2). Some students commented on more than one aspect. Student perceptions of the features of the interactive teaching were shown in Table 8.2 below.

The features of the teaching	Percentage (%) (N=23)
Fostering thinking	61
Emphasizing life application	39
No absolute answers	39
Encouraging active learning	27
Encouraging cooperation	13
Encouraging questioning	13
Learning concepts	13

Table 8.2: Student perceptions of the features of the interactive teaching

- Fostering thinking

Fourteen students (61%) perceived that the intervention teaching encouraged thinking, which enabled them to clarify their concepts and gave them the feeling of learning more. Previously, the students said they often took what the teacher said for granted, so there was little need to think. Even when the teacher asked a question this tended to have a prescribed answer. Through the intervention, they had been guided to employ a more independent and thinking approach to learning biology. A representative comment was:

We can think and infer rather than just following the textbook. We have independent thinking. In the old teaching, although we were allowed to think, we were often following the teacher's way of thinking (S2504).

Students noted they had been encouraged to make a breakthrough in traditional perspectives. For example:

Learn to think from different angles. Some ideas I have never thought before (S2305).

Teacher questions were said to prompt thinking which helped the students clarify their concepts. For example:

When the teacher raises questions, we need to think by ourselves. Very often, the concepts were not as we supposed them to be (S2309).

It appears that the teaching successfully engaged students in thinking to facilitate their cognitive development.

- Emphasizing daily life application

Nine students (39%) indicated they recognised and appreciated the teacher's endeavours to transform the abstract content of the textbook into living examples to help them connect theory and practice. The students stated that this had made the learning more interesting and meaningful for them. The representative comments were:

The teaching taught supplements of daily life rather than that of content knowledge. It emphasises the integration of theory and everyday life (S2502).

The content of the new teaching is more concrete to me. The textbook is more abstract and it seems we learn that just for passing tests. I am more interested in what you taught (S2502).

- No absolute answers

Nine students (39%) commented the teacher gave no absolute answers as conclusions to discussions. To them a couple of the conclusions seemed tentative and uncertain, as one student explained:

Some things are uncertain in the teaching (S2311).

In fact, most conclusions in the interactive teaching fitted with biology concepts. It seems they still ask for a right answer to any question.

- Encouraging active learning

Six students (27%) reached the conclusion that they needed to take responsibility for their own learning to gain real understanding. The students noted they had to engage in active mental work and to decide what to learn. Active attitude was said to help student learning. One stated:

In the new teaching, you need to find out what you are going to learn. The previous teacher transmits knowledge to us, which is hard to remember. But now, we need to think or seek for information. In this type of learning, we are our own masters. If we didn't learn actively, we won't know what we were doing in the class (S2305).

A crucial change here was that the teaching was experienced by the students as more student-centred than teacher-centred although they appreciated the teacher played a crucial role in guiding discussions and making conclusions. One said:

The teacher's role is important too. She will guide the direction of discussion and help us to make conclusions (S2313).

- Encouraging cooperation

Three students (13%) acknowledged that every individual needed to engage in thinking if they were to contribute their part to the discussion so that the whole became greater than the sum of parts. For example:

When everyone devotes his part, the discussion becomes perfect (S2539).

Students realised that an individual could make only a limited contribution and group members interacting with each other were able to bring better learning.

- Encouraging questioning

Three students (13%) pointed out they were more confident in questioning because students respected each other in the teaching. For example:

We can raise questions whenever we have them and needn't worry about raising inappropriate questions because no one will say it's wrong or laugh at you. It's risky to pose too many or inappropriate questions during the traditional lecture classes (S2504).

- Learning concepts and encouraging thinking deeply

Three students (13%) asserted that the new teaching not only provided them knowledge but also guided them to learn deeper, rather than wider, in each topic. One commented:

The teaching content contains the general concepts we should learn and the depth of it is deeper than ever because we have opportunities to think (S2539).

It appears that the teaching not only provided students with knowledge but also highlighted the quality of thought.

Student commentary identified features of the interactive teaching that are consistent with the five principles of the teaching design:

- (1) encouraging active learning supports the Principle 1 *shifting the roles of teacher and student*;
- (2) encouraging questioning and encouraging cooperation are in line with Principle 2 *encouraging student-teacher and student-student interactions*;
- (3) learning concepts, fostering thinking, and no absolute answers match with the Principle 3 *emphasising both the knowledge product as well as the learning process*;

- (4) emphasizing life application conforms to the Principle 4 *linking teaching content to daily life*; and,
- (5) the teaching process of question-and-feedback is congruent with the Principle 5 *adopting assessment for learning*.

Perceived strengths and weaknesses of the interactive teaching

The interview students discussed their perspectives of strengths and weakness of the teaching approach. There were six strengths proposed by the students and the main two were promoting genuine involvement and peers interactions promoting learning. Thirteen students (58%) stated that students seldom dozed, were more focused and had more discussions because of more interactions and the supportive atmosphere for learning. One student noted a change in involvement in two of his peers:

Student S2328 is always inattentive in class, but he begins to be involved in the discussions now. He even made some critical decisions in one of the investigations. Student S2308 has a similar change (S2305).

The reasons for the change were that the teaching provided them more opportunities to interact with the teacher and classmates. They would be embarrassed if they dozed:

The percentage of students dozing in class was almost zero. There are no interactions in traditional teaching, so the students have little sense of involvement (S2504).

My classmates did not doze because everyone was looking at each other in discussions (S2315).

They needed to pay full attention in order to give responses to peers. One explained:

The students who didn't pay attention could not respond to the group mates' questions, so they had to listen carefully (S2318).

When they saw the other students enthusiastically involved in discussions, it gave them the feeling that learning was easy. One said:

Because of the better learning atmosphere, we won't feel learning being difficult (S2502).

Ten students (45%) stated that peer interaction helped them clarify their concepts and inspired them. The students clarified concepts by discussing them with group

members, and because the students used the same language sometimes their explanations were even clearer than the teacher's. Students stated they gained inspiration from other students. For example:

Sometimes, I can't exactly understand what the teacher said, and then I get help from my classmate. Similarly, when I don't know how to apply certain concepts, I suddenly have clear ideas from my classmate's question (S2304).

This view is congruent with social constructivist views of learning, which highlight the importance of peer learning.

These strengths suggested the students valued interactions and experienced social influences in student learning.

The other strengths included the teaching was *relevant to daily life, offered a thinking space, provided opportunities to cultivate their abilities in applying and presenting information, and encouraged active learning*. These have been illustrated in Sections 8.3.1 and 8.3.2.

The interview students proposed the six weaknesses of the teaching shown in Table 8.3.

Weaknesses	Percentage (%) (N=23)
Time management not adequate and no time to prepare	48
Poor preparation for examinations	44
Having problems in adapting to the new teaching	35
Off task behaviour	26
Not providing sufficient knowledge	17
Noisy	13

Table 8.3: Student perceptions of the weakness of the interactive teaching

- Time management not adequate and no time to prepare
Eleven students (48%) mentioned time management problems in discussions and said they could not afford the time to prepare for these. Five considered discussion time was often too long with not enough time left to make worthwhile conclusions.

Three complained that too much time spent in discussion led to the teaching lagging behind the syllabus. A representative comment was:

The discussion time was too long, so the teacher had insufficient time to make conclusions, which made me feel the conclusions were weak and I learned little (S2513).

Three students thought they needed to spend time to prepare before the interactive teaching. They doubted whether they could afford this because they were Grade 12 students who would take the University Entrance Examination soon. For example:

It takes lots of time to prepare and I had no time because I need to prepare for tests (S2311).

Influenced by examination culture, it seemed these three students at least hesitated to invest time in the teaching.

- Poor preparation for examinations

Ten students (44%) conceived they needed unambiguous notes and supplements to earn marks and the teaching did not provide these. Although they did not reject the new teaching, seven students were upset at feeling less confident in preparing for term examinations which generally focused on content. One said:

Some material appears in the term examination, but wasn't taught to us. I feel very frustrated; because you didn't teach it in class and I don't know how to respond (S2525).

Two students thought they lacked of confidence in outlining the main ideas which are the content of tests in the interactive teaching classes. One said:

Sometimes I feel very messy and can't grab the key point. How can I deal with tests? (S2505).

Another revealed his hesitation toward the new teaching under the pressure of University Entrance Examination (UEE):

I know you try to lead us out of the cage, but we have little confidence in preparing for tests. It's risky. Who can promise the new teaching could help us to pass UEE successfully? (S2537).

Here, the examination culture led to student hesitation in accepting the new teaching.

- Having problems in adapting to the new teaching

Although most of the students appreciated being genuinely involved in the teaching, eight students (35%) stated they could not adapt to the new teaching because of a lack of prior knowledge. They put responsibility onto the able students. Two of these students considered they lacked the requisite prior knowledge and were unwilling to think; hence they tended to not pay attention or participate in discussions. One said:

My biology knowledge is not enough and also I do not like doing thinking. If it's my turn to do a presentation, I will ask a group member's help. Sometimes, I didn't listen, so I stay outside the group having no idea about what my group members discussed (S2310).

Two students thought not themselves, but the able students should contribute to discussions and presentations. One stated:

The students who are competent or have high marks are considered to have the responsibility of leading the group they belong to (S2336).

On the other hand, students who were regarded as able considered others contributed little and felt their own work load was heavy. For instance:

My group members did little and I felt exhausted from doing so much work (2530).

These comments suggested students who were reluctant to take responsibility for their own learning tended to have problems in adapting to the new teaching.

- Off task behaviour

Six students (26%) confessed that discussion often accompanied chat. Three of the six students observed that because students were not compelled to speak, some would chat. This, one student argued, led to inefficient discussion. The other two students revealed they did not chat on purpose. They found it difficult not to be influenced by those who were off task. For instance:

I know I need to be focused in the discussion, otherwise it is wasting time. The problem is there are always some students chatting during discussions and not to be affected by them is really difficult (S2309).

This was an example of social influences on student learning, in this case a negative outcome.

- Not providing sufficient knowledge

Four students (17%) commented that they had to spend time doing further reading to get more knowledge because the teaching provided insufficient knowledge. For example:

There is not much knowledge in the new teaching. But if we do some reading after school, we will have more knowledge (S2313).

Noisy was seen as another weakness and is not discussed because of the small number of responses.

To sum up, student perceptions of the strengths of the teaching indicated the importance of peer learning, classroom interactions and the social influences to student learning of biology. On the other hand, student perceptions of the weaknesses of the teaching suggested the examination culture led to student hesitations in accepting the new teaching. Also, students who were reluctant to take learning responsibility tended to not accept the new teaching.

8.3.3 Student suggestions for enhancing the interactive teaching

The students made seven categories of suggestions to improve the interactive teaching, which are detailed in Table 8.4 below.

Suggestions for enhancing the interactive teaching	Percentage (%) (N=23)
Begin earlier and in all science subjects	39
Review the role of the group spokesperson and procedures for forming groups	39
More explicit and closed initial questions and conclusions from the teacher	34
Insist on student preparation	30
Mix transmission and interactive teaching	22
Reduce class size	13
Better time management	9

Table 8.4: Student suggestions for improving the interactive teaching

Begin earlier and in all science subjects

Nine students (39%) suggested that intervention teaching commence at Grade 10

or even earlier, and in other science subjects, because they needed time to become accustomed to it, including managing class time and learning more independently. One proposed it begin from childhood:

The new teaching should begin from elementary school, which would help students be familiar with this type of teaching earlier. We can control the time well gradually and there is no need to worry that we can't prepare for test, if the teacher doesn't teach (S2504).

In the meantime, the students pointed out other subjects did not employ this type of teaching instruction, so that it was hard to transfer the new mode of thinking to those subjects where the focus remained on factual knowledge. For example:

Being affected by the teaching, I began to use thinking to learn in other subjects. However, in those classrooms, the teacher still used old teaching approaches, which made me feel it was hard to have different types of lessons (S2539).

These opinions suggested students appreciated the teaching, but it was difficult for them in that they were required to take a completely different approach to learning and hence become accustomed to a different learning culture.

Review the role of the group spokesperson and the procedures for forming groups

Nine students (39%) suggested selecting a reporter through volunteering or drawing lots, and forming groups through drawing lots or based on friendships or cognitive competence. They complained a couple of group spokespersons did not always have complete commitment. Even if students were assigned to be the spokesperson they could remain passive. This ran counter to the original purpose of establishing a spokesperson, which was to require equal participation. Five students suggested the spokesperson be selected by drawing lots. One explained:

The spokesperson didn't do their duty well. Sometimes, I would teach them what he should say, but they still forgot. The arrangement of spokesperson is encouraging everyone to express opinions, obviously, under this situation; but the purpose is not accomplished (S2305).

Two students thought there was no need to separate students into groups. Students might not discuss with the one they were not familiar with. He said:

Some students are introverts. They will keep silent, if their group members are not their good friends (S2305).

Individual cognitive differences were said by two students to lead to difficulties in communicating and generating conclusions. For instance:

The students who have a similar level should be in the same group, otherwise it will be difficult to communicate and make decisions (S2502).

More explicit and closed initial questions and conclusions from the teacher

Eight students (34%) emphasized the importance of explicit conclusions to discussion and suggested the teacher ask more closed initial questions. They expected a final answer to be confirmed by the knowledgeable teacher. For example:

When the final conclusions are going to come out, the teacher had better emphasise the others are wrong rather than say they were not accepted by scientists so far (S2504).

They suggested the teacher provided questions with clues to focus thinking as explained in the following comment:

The teacher had better provide closed rather than open questions and more clues at the beginning of discussion (S2513).

This implied that the influence of transmission teaching remained and the students were still concentrating well obtaining knowledge.

Insist on student preparation

To gain the best benefit, seven students (30%) proposed that all students are required to prepare for lessons by reading relevant information before the teaching; this is to ensure they had sufficient prior knowledge to infer and discuss. Without advance preparation, discussion and presentation could be insubstantial. One explained:

If the group members didn't prepare in advance, then the discussion will be boring and the reporter will have little outcome to present (S2530).

It appears that students realised the importance of prior knowledge and that for the new learning approach they needed to learn more actively.

Mix transmission and interactive teaching

Five students (22%) suggested conducting transmission and interactive teaching

alternately. They suggested teachers giving a lecture with a detailed handout and then provide them with a few questions to discuss.

It is better that we have part of the class time using the transmission way and another part using discussions; meanwhile provide us some organised material. It saves our time, although we students can do this too (S2513).

It seemed that the students still relied on the teacher. They recognised they could organise material for themselves but would rather the teacher do this because it required less time from them. Even when they had received the new teaching for five weeks; their views of learning remained unchanged. This also suggested the cultural influence on them.

A reduction in the class size and better time management by the teacher were suggested by a few students.

The students appreciated the interactive teaching and suggested beginning the teaching in an earlier grade and using it in all science subjects to help them become accustomed to the use of thinking as a learning strategy and learning independently. They recognised the need to contribute ideas and sense the importance of prior preparation. Some suggestions addressed the need for all students to contribute to under the new approach. However, influenced by their prior experience of learning and their concern with examinations, they suggested a blend of transmission and interactive teaching with explicit roles.

8.3.4 Summary of student perceptions of the interactive teaching

Students perceived they needed to adopt thinking as a learning strategy and learn actively to develop real comprehension in the interactive teaching classes. The importance of prior knowledge was emphasized by the students in talking about constructing new knowledge. They experienced the benefits of peer discussions, through which they learned how to appreciate alternative ideas; their alternative conceptions were uncovered; and, their thinking skills were enhanced. Their statements about what and how they learned from discussions suggested many of them had moved towards a more constructivist approach to learning. The students perceived that the intervention teaching helped them connect scientific concepts with their own lives and experiences. The features of interactive teaching

identified by the students are consistent with the five principles of the teaching design.

Students perceived the main strength of the interactive teaching was that it encouraged them to become genuinely involved because of the classroom interactions. The importance of peer interactions and the social influences to their learning biology were also emphasized. On the other hand, their perceptions of the weaknesses of the teaching suggested the influence of an examination culture which emphasized good grades and their prior experience of learning biology provided a challenge as they tried to adapt to the new approach. Student suggestions indicated while they appreciated the key aspects of the new teaching, they struggled to adapt to a new culture for learning.

8.4 Comparing student responses between the interactive teaching classes and traditional lecture classes

Seventy students from intervention classes and 195 students from traditional classes were surveyed (For the questions, see Appendices 9.1 and 9.2, Questionnaires 2A1 and 2A2) to determine their perceptions of the interactive and traditional lecture classes.

8.4.1 Comparing student perceptions of learning

The students from intervention and traditional classes responded to questions about their learning. Their responses are summarised in Table 8.5 below.

Questions	Agree % IS (TS)
1. I spend much time in thinking and negotiating with my classmates in the current lecture classes.	81 (28) ***
2. I spend much time copying notes in the current lecture classes.	7 (40) ***
3. Clear notes would be better than discussion for learning.	24 (43) ***
4. I would like to seek more information about what we have discussed.	59 (37) ***
5. I know how to get better learning from the biology classes.	46 (34)
6. I can apply what I have learned in the current lecture classes to my daily life.	66 (54)

Table 8.5: Student perceptions of learning in the interactive teaching and traditional lecture classes ($N_{IS}=70$, $N_{TS}=195$).

Key: (1) $p < 0.05^*$, $p < 0.01^{**}$, $p < 0.005^{***}$ (Mann-Whitney U test);

(2) IS: intervention students responding to survey;

TS: traditional students responding to survey.

Eighty-one percent of the intervention students agreed they spent time engaging in thinking and attempting to reach agreements with their classmates. This compared with 28% of students from the traditional classes. The percentage of traditional students who declared they spent most of their class time copying notes (40%) was higher than that of intervention students (7%). Nearly half (43%) of the traditional students believed that clear notes provided them with more knowledge than class discussion. This percentage was nearly double than that of the intervention students (24%). The intervention students showed a stronger desire in seeking more information (59%) than the students from traditional classes (37%), which implied the intervention students were more willing to actively seek out additional information. The differences between the students in the intervention and traditional classes in these four comparisons were statistically significant ($p < 0.005$) (Mann-Whitney U test).

More intervention students thought they knew how to get better learning from biology classes (46%) and considered they had more experiences in linking their learning to everyday life (66%) than the students of traditional classes (34% and 54%, respectively). Although differences existed in the two groups in these two responses, they were not significant at the level of $p=0.05$ (Mann-Whitney U test).

Overall, the traditional and intervention student perceptions of learning were different. Students in the intervention classes recognised they had engaged in thinking and interacted with peers. Most of them sought information on their own initiative. Few traditional class students reported they thought and interacted with their classmates. They indicated less willingness to pursue further information as might be expected if they were more passive learners.

8.4.2 Comparing student perceptions of teaching

The 195 traditional and 70 intervention students were surveyed about their perceptions of teaching and their responses are set out in Table 8.6 as follows:

Questions	Agree % IS (TS)
1. The teacher spent much time in student discussions.	51 (20) ***
2. The teaching content is related to my daily life.	90 (72) ***
3. The teaching way is monotonous.	36 (59) ***
4. The teaching content is not abstract for me.	70 (50) ***
5. From group and whole class discussion, my concepts were clarified more clearly.	69 (32) ***
6. The current teaching way is very effective to help us acquire lots of knowledge in a short time.	34 (43)
7. The teaching way could stimulate my interest in learning biology.	57 (51)

Table 8.6: Student perceptions of teaching in the interactive teaching and traditional lecture classes ($N_{IS}=70$, $N_{TS}=195$).

Fifty-one percent of the intervention and 20% of the traditional students agreed the teacher spent time in student discussion. More intervention students

announced the teaching content was related to their daily life and not abstract (90% and 70% respectively) compared with the traditional group (72% and 50% respectively). This suggests the intervention students had noticed the shift in focus to link theory and practice. More traditional students (59%) considered their teaching to have been monotonous than the intervention group (36%). Sixty-nine percent of intervention students alleged that their concepts were clarified via group and whole class discussion, a higher proportion than the traditional students (32%). The differences in these five responses were statistically significant at $p=0.005$ level.

More traditional students (43%) felt teaching helped them acquire knowledge quickly and 34% of the intervention students thought this was the case. More intervention students (57%) agreed the new teaching approaches could stimulate their interest in learning biology compared with 51% of the traditional students. However, the differences were not statistically significant ($p>0.05$) (Mann-Whitney U test).

8.4.3 Comparing student overall evaluation

The two groups of students were asked their perceptions about the overall teaching. Their responses are presented in Table 8.7 below.

Questions	Agree % IS (TS)
1. I am not sure I can cope with tests by the current lecture classes.	66(42)***
2. The time passes quickly in biology classes.	73(46)***
3. I am very satisfied with the current biology classes.	70(60)*
4. I like the current biology classes.	61(57)
5. The current lecture classes are helpful to my learning in biology.	60(62)

Table 8.7: Student overall evaluation of the interactive teaching and traditional lecture classes ($N_{IS}=70$, $N_{TS}=195$).

Sixty-six the intervention group were unsure whether they could cope with tests. Only 42% of the traditional group had the same feeling. This suggested that the students did not always appreciate when the interactive teaching and learning connected with the examinations. Seventy-three percent of the intervention group felt the time passed quickly in biology classes, but only 46% of the traditional group had the same feeling. It appears that more intervention students were concentrating on or enjoying their class than the traditional students. Their differences in this response were very significant at the $p=0.005$ level. Seventy percent of intervention and 60% of traditional students were satisfied with the current biology classes. This degree of satisfaction with biology classes, is statistically significant ($p < 0.05$). Obviously, a higher proportion of the intervention students were satisfied with the interactive classes.

A similar proportion of the traditional and intervention students liked their biology classes (57% and 61%, respectively) and believed their biology classes were helpful to their learning in biology (62% and 60%, respectively). There was no statistically significant difference between the groups in these two categories.

From the data, it is evident that most intervention students perceived they were engaged in thinking, interacted with their peers to reach consensus and were willing to seek additional information. They thought the teaching content was concrete to them and related to daily life. Through discussions their concepts were clarified. However, although the students perceived the intervention classes apparently provided them benefits in thinking, applying and clarifying concepts, they had less confidence in preparing for tests compared with the students in traditional class. Overall, the intervention students had greater satisfaction than the traditional students.

8.5 Student scientific epistemological views (SEVs)

In this section, the changes of student SEVs during the intervention and the relationship between these beliefs and their view of learning and their thoughts about the interactive teaching are examined.

8.5.1 The changes of student SEVs

Tsai's Pomeroy Questionnaire was adopted to investigate student SEVs in this study. The researcher administered Tsai's Pomeroy Questionnaire twice, before and after intervention, and the objects were 69. In Tsai's Pomeroy Questionnaire, students having strong beliefs about constructivist views would have high scores (see Section 4.4.2). Twenty-three of the 69 students in the intervention with a score between 83 and 64 were classified as having more constructivist views before the study. Twenty-one students with a score between 56 and 46 were considered to hold more objectivist views. Twenty-five students were considered to have indeterminate views. There were no changes found in the student beliefs about the nature of science over the intervention period (Wilcoxon test, $p > 0.05$). This suggests that student beliefs about the nature of science are hard to change in a short time.

8.5.2 The relationship between student SEVs and their views of learning

Student pre- and post-scores for Tsai's Pomeroy Questionnaire were averaged and are shown in Table 8.8. This was as a basis of their SEVs to investigate the relationship between these beliefs and their views learning (in this section) and their thought about the interaction teaching (in the next section).

Code	Score								
2301	83	2501	67	2538	61	2303	58	2329	53
2512	79	2302	66	2317	61	2517	57	2333	53
2314	77	2519	66	2506	61	2504	57	2310	53
2318	74	2530	66	2524	61	2513	57	2514	52
2330	73	2518	66	2306	60	2515	57	2529	52
2502	73	2535	65	2308	60	2537	57	2319	51
2531	73	2313	64	2307	60	2309	56	2523	51
2528	72	2539	64	2323	60	2525	56	2311	51
2526	72	2305	64	2325	60	2304	56	2315	50
2534	72	2533	63	2527	60	2326	56	2327	50
2503	71	2321	63	2312	59	2332	54	2536	50
2507	69	2324	63	2336	59	2522	54	2532	48
2511	69	2509	62	2322	59	2320	54	2316	46
2331	67	2516	61	2505	59	2328	53		

Table 8.8: The outcomes of the Tsai's Pomeroy Questionnaire (N=69).

The post intervention interview data associated with the outcomes of the Tsai's Pomeroy Questionnaire indicated students who were more likely to hold constructivist views of science tended to learn more independently and consider that they needed to take responsibility for their learning. In their minds, the teacher role was as a helper, and teaching should not be dominated by him/her. They tended to be more willing to appreciate alternative views and find out possible reasons instead of merely receiving facts. Student S2502, who scored 73 in the Tsai's Pomeroy Questionnaire, is representative of students with more constructivist views. She thought that teachers are responsible for stimulating student thinking and the best strategy to reach this goal is to use questions. In her words:

A teacher's responsibility is to help students think by asking them questions (S2502).

Student S2312, who was also scored 73, argued it is not necessary for teachers to take all responsibility of student learning in a class. He said:

I do not think the success of a class mostly depends on the teacher (S2313).

Student S2507 (scored 69) asserted it was important to appreciate alternative views, and that interaction with others helps learning. In his words:

We are able to know what other people think and what the differences between their and our thoughts are. It increases the breadth of our knowledge (S2507).

Student S2534 (scored 72) desired to understand the basis of knowledge rather than only passively accepting it. He stated:

Textbooks often give us ready-made information, but I do want to know why (S2534).

On the other hand, students whose Tsai responses and interviews indicated they were more likely to hold objectivist views of science tended to believe teachers ought to be knowledgeable and see the transmission of knowledge as a teacher responsibility. For example:

Teachers need to know everything their students are asked in class time (S2327).

The teacher needs to directly teach the students; otherwise the students do not know what to study (S2525).

This group tended to view learning as a passive activity. A representative comment was:

To us, active learning is impossible (S2515).

Where these students considered the transmission of knowledge as a teacher responsibility, they consider it was a student responsibility to study for tests.

A student's responsibility is to study hard to earn marks (S2310).

These results indicated that the intervention students held a range of views of learning and these appear to be related to their epistemological beliefs of science.

8.5.3 The relationship between student SEVs and their thoughts about the interactive teaching

An examination of student responses to the interactive teaching indicated that students who were more inclined to have constructivist views of science tended to support the interactive teaching. On the contrary, students who were more inclined to have objectivist views of science also tended to show negative or neutral responses to the teaching.

Fourteen students (61%) affirmed the value of interactive teaching. Eight students had strong constructivist views as indicated by Table 8.8 and two had middle constructivist views. Interestingly, two students had views that could be classified as objectivist. They thought interactive teaching was feasible, worth experiencing and related to daily life and had developed strategies to prevent low marks. These students reported that initially they had thought such teaching was not feasible but had changed their minds because of the help the teacher provided.

I feel that's 'mission impossible' at the beginning of the teaching, but with the teacher's help I adapted to it gradually and I feel great now (S2330).

They valued learning knowledge that they could relate to daily life, even if it might not be tested.

Although some knowledge related to daily life in the new teaching won't appear in the test, it is worthwhile to know it (S2535).

These students did not consider the new teaching approach would result in them gaining low marks. They were prepared to take responsibility for ensuring their understanding by reading the textbook and consulting with the teacher.

I don't think the teaching will cause me to get low marks. I can read the textbook by myself and consult the teacher if I have any questions. Therefore, I don't think it's an inappropriate time to conduct the new teaching (S2539).

Therefore, they had a high opinion of the interactive nature of the new teaching.

The new teaching is very lively and almost every student is involved in it. I feel the new is better than the old teaching (S2511).

Seven students (30%), who tended to hold more objectivist views of science based on a score of less than 56 (see Table 8.8) showed less appreciation of the teaching. They said they still felt uncertain about what was the right answer at the end of a discussion. They requested clear and absolute answers.

Although there are many opinions in the class discussion, sometimes, we still feel that we have learned little as those opinions are messy and uncertain (S2311).

I didn't exactly know which conclusion in the discussion was right (S2309).

Not all of the seven students who had negative opinions were definitely against interactive teaching. Two of them conceived that the teaching was best for able students or students with good marks who could easily discuss ideas and pick up the key points from a discussion.

Interactive teaching is adequate for those students who have high marks and are smart or who have low marks but like discussing way (S2310).

They thought less able students might find the process complicated.

For some less able students, they might feel the content was very complicated, and so they don't exactly understand (S2304).

Two students (9%) did not display their likes or dislikes on the teaching and their responses were neutral.

In short, student beliefs about the nature of science are hard to change in a short time. Students who were more inclined to have constructivist views of science, tended to consider that they needed to take responsibility for their learning, prefer to interact with others and use thinking as a strategy in learning. They were more supportive of the interactive teaching. Students who were more inclined to have objectivist views of science, tended to consider that the teacher needed to take responsibility for students learning, learn passively and study for tests. They showed less appreciation of the teaching.

8.6 Comparing the traditional and intervention student test achievement

To gauge the impact of intervention programme on student test achievement, the intervention students and traditional students were asked to take a pre-test and a post-test. Sixty-eight intervention and 191 traditional students took both tests (see Section 4.4.1 for the procedures). Hake (1997) defined that Gain (%) = (postscore-prescore) / (100-prescore) × 100%. This shows a shift in class understanding over the course of the teaching. This shift was greater for the intervention classes. The class average marks and gain percentage of the two groups of students in the pre- and post- test are presented in Table 8.9 below

Classroom type	No. of students	Class average mark		Gain (%)
		Pre-test	Post-test	
Traditional class 1	53	42.04	55.04	22.43
Traditional class 2	49	48.30	60.57	23.73
Traditional class 3	47	46.30	59.32	24.25
Traditional class 4	42	50.67	63.14	25.28
Intervention class 1	34	51.76	66.35	30.24
Intervention class 2	34	48.59	63.06	28.15
Average of traditional classes	48	46.59	59.29	24.65
Average of interventional classes	34	50.18	64.71	29.16

Table 8.9: The comparison of student marks and gain percentage between traditional and intervention classes before and after the intervention

When the researcher interviewed the students after the intervention, many of them indicated that they worried that they might score a low mark in the term examination. This was not the case when students were considered as classes. Although the gain in the traditional and the intervention classes were not significantly different based on a two-tail t-test ($p=0.1658>0.05$) and the class ranking in post-test was the same as in pre-test, the gain of the traditional classes was on average lower (24.65%) than that for the interventional classes (29.16%).

There was not a statistically significant difference in student test achievement between the traditional and intervention classes, but the intervention students reported much greater satisfaction in their learning and the teaching (see Section 8.5).

8.7 Summary of the evaluations of the interactive teaching

During classroom conversations, students demonstrated that they could construct their own knowledge through interactions with the teacher, peers, and their physical world in the social context. They demonstrated they were able to reflect on their ideas, cooperate with each other and apply, clarify and understand biological concepts. All these experiences facilitated student learning in a way that is consistent with the five principles for the design of the intervention and the senior high school biology curriculum in Taiwan.

Generally, the interview students made positive comments about the interactive teaching. In constructing new knowledge, students perceived they were required to employ prior knowledge, adopt thinking as a learning strategy and learn actively to reach real comprehension. Student perceptions of the strengths of the teaching suggested the importance of classroom interactions with the teacher and peers to support their learning of biology. On the other hand, their perceptions of the weaknesses of the teaching suggested the examination culture and student prior conceptions about learning posed a challenge to their acceptance of the new teaching when it required them to take more responsibility for their learning.

The perceptions of teaching and learning of the traditional and intervention students were significantly different. To review learning, the intervention students said they were more likely to employ thinking strategies, learn through interactions with the teacher and peers, and to seek out information. In traditional classes, student survey responses were as might be expected if they expected to be a more passive learner. To summarize the teaching, a high proportion of the intervention students considered the teaching content to be linked with daily life so that it was less abstract, and presumably more meaningful. Although the intervention students perceived the teaching approaches promoted their cognitive

development, they had less confidence they were well prepared for tests than students in the traditional classes.

Whether students were supportive of the interactive teaching was generally related to their epistemological beliefs. The students, who held more constructivist views of science, as determined by Tsai's Pomeroy questionnaire, perceived they needed to learn actively and tended to be more supportive of the interactive teaching. The students, who held more objectivist views of science, were more likely to attribute responsibility to the teacher and favour passive learning approaches. They tended to be less supportive of the interactive teaching. Evidence was provided that student SEVs did not change in the five weeks of the intervention.

Student test achievements were comparable in the traditional and interactive teaching classes, but more of the intervention students were satisfied with their classes than the traditional students. The intervention was able to increase student affective outcomes whilst maintaining academic performance.

Open investigation is the other half of the intervention programme. The following chapter will articulate the evaluation of student learning outcomes in the open investigations.

Chapter 9

Evaluating the open investigations

9.1 Introduction

In open investigations, students have more autonomy in defining problems, choosing methods and arriving at solutions (see Sections 3.4.6 and 7.2). This contrasts with closed experiments, in which the task, procedures and outcomes are determined for them. Through open investigations, it is hoped that the students in this study would develop knowledge and understanding of scientific ideas about biology as well as an understanding of how scientists study the natural world. This chapter illustrates how and to what extent the students in the study developed their conceptual and procedural understanding.

In this chapter, qualitative data from student work sheets (student planning and self-evaluation sheets, see Appendices 11 and 12), group reports and laboratory dialogues along with quantitative data from Questionnaire 2B1 and 2B2 (see Appendix 10) and Confidence Questionnaire (see Appendix 8) is presented. Seventy-three Grade 12 students attended the intervention programme (195 students were in the control group) in the fall of 2001. Their backgrounds were detailed in Section 4.4.1.

Evidence of student learning in open investigations - how they planned and conducted them, and the conclusions they reached – is set out in Section 9.2. Student evaluation of what they liked and their performance, learning outcomes and confidence in doing open investigations are presented in Section 9.3. Section 9.4 describes how intervention students viewed closed experiments compared with open investigations. Also, the perceptions of the students who did the open investigations are compared with the perceptions of those who did the closed experiments. A summary evaluation of student learning in open investigation is included in Section 9.5.

9.2 Evidence of student learning in open investigations

There were two intervention classes involved in this study, which are Room 23 and Room 25, and three investigations in this study. Task 1 was the observation of cells. The teacher prepared four animals/plants items and the students brought in one item they would like to observe. This task was used to introduce the students to the ‘new rules of engagement’ and to begin to accustom them to the more open non-observational work which would follow. The non-observational work - Tasks 2 and 3 were fair-tests (for further details of the three tasks see Section 7.3.3). The task and work sheets provided hints and questions to guide students in how to design the investigation. In addition, the teacher circulated between the groups to provide advice and discuss ideas.

In this section, students’ responses are categorized based on the five principles. Student learning outcomes were highlighted in the stages of planning for and gathering empirical data, and drawing conclusions in all the three tasks.

9.2.1 Planning in open investigations

Student planning was mainly guided by the questions on the student planning sheets. The intended learning outcomes for planning were; consideration of relevant knowledge, making hypotheses, considering factors and/or identifying variables, and taking the required measurements. These require students do more thinking than previous closed experiments.

Students considered relevant knowledge

The students were prompted in Task 1 to consider employing their prior knowledge. Sixty-eight students returned the task sheet. Their written comments detailed the knowledge they thought should be considered including:

- (1) knowledge they had learned related to the manipulation of a microscope (56%, 38 out of 68);
- (2) cell biology ideas they had learned in high school (24%, 16 out of 68); and,
- (3) the use of a dye in observing a cell (20%, 14 out of 68).

The students were able to list knowledge on how to use the microscope and its mechanism of image formation, the generalized picture of the cell, and the dyeing method. For instance, two students suggested:

It is not good to adjust coarse adjustment knob under high magnification (S2312).

I need to consider how to dye a cell to see the nucleus clearly (S2511).

Students made hypotheses

In traditional experiments, students were not usually required to make an hypothesis. Hence, the teacher needed to remind the intervention students to do this in the planning stage of the tasks. In Task 2, 66 students returned their planning sheets. Of these, 46 had made hypotheses and the other 20 had not. These hypotheses were classified as predictive hypotheses, descriptive hypotheses and explanatory hypotheses under the classification system developed by Wenham (1993).

- (1) Predictive hypotheses (42%, 28 out of 66) , for example:

Most of the manuals on dieting suggest eating tomato, so I reckon tomato will contain the least calories (S2322).

- (2) Descriptive hypotheses (21%, 14 out of 66) , for example:

The fruit with the longest time during colour change contains least carbohydrate and is the best choice for Mary (S2519).

- (3) Explanatory hypotheses (6%, 4 out of 66), for example:

The fruit containing the least carbohydrate is the best choice for Mary...because carbohydrate is the main energy resource and cause of gaining weight (S2305).

Most hypotheses made were predictive. Forty-two percent of the students simply predicted what would happen in the investigation. Twenty-one percent of the students provided a descriptive hypothesis. That is, they simply described what they thought to be the case in the investigation. These two types of hypotheses required less relevant prior knowledge than explanatory hypotheses. Only 6% of the students gave a reason for the hypothesised effect thereby providing an explanatory hypothesis.

Nearly a third (31%) of the students did not make any hypothesis. This was student first experience of making a hypothesis so perhaps it was not surprising that many of them struggled with this.

Students considered factors and identified variables

Student ability to consider factors and identify variables was evident in all the three investigative tasks, although a few students confused independent, dependent and control variables. Student consideration of factors and variables in Task 2 is provided next as evidence of their ability to do this.

In Task 2 the teacher provided the students with four types of fruits and asked them to design an investigation to determine which one was better for a person on a diet. She provided information about the proportion of carbohydrate, lipid and protein in each fruit. Student actions are described here to demonstrate how students could consider factors and identify variables.

The students first confirmed from the given table that the main source of calories was from carbohydrate compounds, especially sugar. Then all groups decided to test for sugar. Students identified seven independent variables, which are set out in Table 9.1 below.

Independent (operating) variables	Percentage (%) (N=66)
Fruit type	100
Heating	29
Adding Benedict’s solution	17
The method used to process the fruit – juice and scrape	12
Saliva	12
Concentration of the fruit juice	11
Adding iodine solution	6

Table 9.1: Independent variables students identified in Task 2

All students correctly identified the fruit type as an independent variable. Nineteen students (29%) regarded heating as an independent variable. Eleven

students (17%) speculated that the Benedict's solution used to test which fruit contained the most sugar was an independent variable. Some proposed this variable at the planning stage, but changed their minds in their final oral or written report. Some students thought that if they kept only the fruit juice and discarded the fruit residue they might lose some of the sugar (12%). Hence, they considered the method for processing the fruit as an independent variable. Eight students (12%) explained that the samples might contain starch which was considered by the students that it could be an independent variable, so they added saliva to hydrolyse it to glucose. Four students (6%) added iodine solution to test for starch. Seven students (11%) considered the concentration of the fruit juices might be too high, which might be another independent variable, so they decided to dilute the juices. These responses showed the students had thought deeply in considering the independent variables. If the teacher had provided only one fruit and asked them to squeeze the juice, add Benedict's solution and heat the product the students would not have considered so many factors as independent variables. This said, the students in their self-evaluation described the investigation as difficult because of the need to consider so many variables.

Students proposed five dependent variables for Task 2 as set out in Table 9.2. Most students (85%) could point out that the colour change after heating with Benedict's solution was what they needed to record. A few students (8%) also tested for starch using iodine because they thought the fruit might contain starch. Time for a colour change, the amount of sugar and Benedict's solution were identified by a small number of students. These should not have been seen as dependent variables.

Dependent variables	Percentage (%) (N=66)
Colour change after adding Benedict's solution and heating	85
Colour change after adding iodine solution	8
Time for colour change to occur	8
Amount of sugar	3
Benedict's solution	3

Table 9.2: Dependent variables students identified in Task 2

The students identified eight control variables to be kept constant to make the investigation ‘fair’ (see Table 9.3). Most of them (88%) thought it was important to control for the amount of fruit. Nearly three quarters (73%) mentioned heating time and temperature. However, only slightly more than a half (55%) stated that the amount of Benedict’s solution should be kept constant. In the context of student ideas about what were independent variables, other acceptable control variables were; the volume of water for dilution, the volume of saliva, and the concentration of the Benedict’s and iodine solution, if the students considered the concentration of fruit juice, saliva and iodine solution as independent variables.

Control variables	Percentage (%) (N=66)
The amount (mass or volume) of fruit, fruit juice and scraps	88
Heating time and temperature	73
The amount (mass or volume) of Benedict’s solution	55
The volume of water for dilution	11
The volume of saliva	6
The concentration of Benedict’s and iodine solution	3
Pressure	3
Blank	2

Table 9.3: Control variables students identified in Task 2

Students make the required measurements

Task 3 provided clear evidence that the intervention students could identify the measurements they needed to make. In this task, the students were provided with living cells (pork livers, carrots, cucumbers and potatoes) and asked to test for the activity of catalase (an enzyme). The teacher provided the information that catalase decomposes hydrogen peroxide to water and gas. The students indicated that seven measurements were required to carry out the task. These are shown in Table 9.4 below.

Measurements required	Percentage (%) (N=55)
Volume of gas produced	71
Amount (mass, surface area or volume) of a sample	62
Reaction time to produce gas	31
Volume of H ₂ O ₂	29
Amount of heat energy added and length of time for heating	7
Generating velocity of gas	7
Concentration of H ₂ O ₂	4
Time of injecting H ₂ O ₂ into the sample	2

Table 9.4: Measurements students were required to make in Task 3

Thirty-nine (71%) students measured the volume of gas produced to decide the activity of catalase. This action was based on the information given in the worksheet in Task 3 that catalase decomposes hydrogen peroxide to water and gas, so the volume of gas produced indicates of the activity of catalase. Thirty-five (62%) students measured either the mass or volume of their samples. One group of students insisted on measuring the surface area of the pork liver to increase the accuracy of their investigation. To do this they employed a cork borer to cut the same dimension of from each sample and keep the same surface area. This group of students indeed conducted a more precise investigation than the students who measured mass or volume because the surface area of a living tissue determined the amount of catalase in contact with the hydrogen peroxide. Seventeen (31%) students suspected that the gas was produced more quickly when there was more catalase; therefore they measured the reaction time to produce a limited volume of gas. However, this is not always true because the rate of gas production also depends on the type of sample. Some samples can produce gas slowly but last for a long time and some can produce quickly but shortly. These two types of samples might produce the same amount of gas. Sixteen (29%) students considered they needed to know the maximum amount of H₂O₂ to react with pork liver and so they measured the amount of H₂O₂ they added. This indicated that students understood that an enzyme can only bind with a limited amount of substrate and that they

needed to measure the amount of substrate; otherwise, they might add too much H₂O₂.

To sum up, students working on the three investigative tasks indicated an ability to connect relevant prior knowledge to the investigations they were doing and to make appropriate hypotheses at the beginning of an investigation. They were able to consider factors and identify variables in terms of the hypotheses they had made and to make the required measurements in the planning and conduct of investigation. These data showed that the students thought more deeply than they did in closed experiments.

9.2.2 Gathering empirical data in open investigations

When students gathered their own data, they evidenced thinking through question-feedback interactions with the teacher and developed an appreciation of the importance of a control in the group. Group leadership and group work were seen as promoting productive outcomes when students worked to gather empirical data during open investigations.

Students evidenced deeper thinking through question-feedback

The students could not proceed to the conclusion of an investigation unless the problems they encountered in doing it were resolved. In traditional experiment classes, students could approach the teacher and request a direct answer when they encountered a problem. During the open investigations, the teacher encouraged them to resolve their own questions with her guidance. This guidance could be either explicit or implicit, depending on the context. For example, in Task 1 a student asked:

S2535: Is there a nucleus in a toad red blood cell? I remember that there is no nucleus in an animal red blood cell.

This student expected an answer from the teacher. However, the teacher provided him with suggestions to stimulate his thinking.

T: You can choose to either adjust the light to see whether there are any nucleoli inside or use other ways to make sure.

S2535: Like dye?

T: It is a good idea to try it!

S2535: O.K. I need some methyl blue solution ... Now I see their nucleoli.

Students were encouraged to make inferences about what they observed through the teacher's questioning. For instance:

S2516: The spider's head is transparent. I can't see its blood circulation.
T: Does this mean it does not have blood circulation?
S2516: It should have.
T: Then why didn't you see it?
S2516: Umn.... Perhaps it doesn't have any hemoglobin, so it's hard to see.

The above dialogue indicated that with the teacher's help the students engaged in thinking and subsequently were able to make scientific inferences.

Students sensed the importance of a control group

In Task 2, only three of the eleven groups of students set a control. It seemed that the students did not really understand the meaning and function of a control group. They did not consider the background colour until they had problems confirming whether there had been a colour change with the Benedict's solution. Subsequently, they developed a control.

S2530: The grapefruit juice didn't have any colour change.
T: Did you compare with the control?
S2530: We didn't make any control. But it is not too late. We can make one now.
T: How many independent variables do you have now?
S2515: Two. One is adding Benedict's solution and the other one is heating. We can make two controls now. (After that) There is still no colour change.
T: Did you think about the background colour?
S2515: I might need a white paper behind the tube as a background.
S2530: It is greener now, so it means there are sugars in the grapefruit, but not much.

In this case, the students realized they need to set a control group and they demonstrated they could do it.

Group leadership and group work promoted productive outcomes

Group work was used to provide students with more opportunities for interactions. The three investigative tasks required the students to work in groups. The teacher did not demand that a group nominate a leader. However, she found that one or two students in each group took up this role, allocating work and developing conclusions to support the conduct of the investigations. The following dialogue reveals how student S2504 and 2516 led their group to work. Differently from other groups, there were eight students in this group because the students had

insisted on working with their friends. Led by student 2516, some students set up the device for collecting gas. Student 2504 simultaneously provided suggestions to student 2516 about setting up the gas collection device and led the remainder of the group in processing the vegetables:

S2504: Are they all cucumbers? The potato cube is too big.
S2532: How to cut the pork liver? It's hard to cut.
S2526: You don't have to cut if you chew it then spit out (laughing).
S2504: You need to be careful. The surface areas are going to be different.
S2532: How about I cut like this?
S2504: Great! You really did a good job!

Student 2504 praised her peers who worked well and reminded others about what had been overlooked.

S2516: It's hard. It must be leaking somewhere. I have no way.
S2511: It is indeed hard.
S2516: It's too slow (adding H₂O₂ drop by drop). Pouring directly is better than that. Why there is no reaction? Could you shake to see what is going to happen?
S2504: The reaction is already there. Have a close look. (S2504 provided S2516 with a suggestion)
S2516: But it doesn't push the syringe.
T: Do you think there is sufficient oxygen to push forward with the amount of sample?
S2516: The reaction is just beginning. It's no problem. The oxygen will come out more and more.

Student 2504 emphasized when interviewed that there had to be someone to lead a group. In order to be a good leader she prepared before each class. As a result, she was clear about what was to be done and was confident in making decisions. She revealed in an interview that she often deliberately conveyed the feeling “We need you. We are fortunate to have you here”, to obtain her group members’ cooperation. It seemed she was competent in leading her group. Not all leaders were like this. Some students complained their group did not have an effective leader. For example:

Student 2530 just kept doing it and did not tell us what we should do. We had no idea about what he was doing, so we had no way but to sit aside, and then he blamed us for doing nothing (S2515).

The teacher observed that a group with good leadership and a cooperative atmosphere had more detailed planning, conclusive discussions and fruitful content in oral or written reporting than groups without competent leadership.

To sum up, students were able to manipulate equipment, engage in thinking, make inferences based on what they observed, make convincing interpretations, and know how to observe and use a control group. Good leadership and group work facilitated more productive open investigations.

9.2.3 Drawing conclusions in open investigations

In the open investigations, the most important investigative skill is using data to reach conclusions. When making conclusions the students showed that they had made thoughtful observations and that they could draw inferences to explain what they observed and employ the investigation outcomes as evidence. They also demonstrated they could construct knowledge through cooperation and could work together to make their learning meaningful.

Students had more thoughtful observations

Students in the open investigations may draw thoughtful conclusions based on the data shown in their individual report. For example, in Task 1, students created detailed descriptions of the cells they observed. The comparisons they made between cells were more thoughtful and detailed than those by the students who participated in the traditional closed experiments. Subsequently, their comparisons led to them draw some surprising conclusions. These were helpful in clarifying their alternative conceptions. For example:

It is not true that the plant cell is more regular than the animal cell. The red blood cell and the Elodea cell are regular, but the epidermis of the long life flower's leaf and human mouth are both irregular (Group 1 in Room 23).

However, during the observing activity something unexpected like air bubbles caused confusion for some students. They regarded the bubbles as objects they needed to observe. At this moment, direct teaching was needed to help them clarify ideas and focus their observation.

Students made inferences to explain what they observed

The students learned actively and attempted to make inferences by utilising their background knowledge to explain the phenomena they have observed. For example, student S2305 made Table 9.5 to compare the differences between the leaf tip and the stalk of Elodea.

Location	Chloroplast	Protoplasm flow	Dyed the nucleus
Leaf tip	Many	Slow	Not clear
Leaf stalk	Few	Fast	Clearer

Table 9.5: The comparison of the different part of Elodea's leaf made by student 2305

He observed that the number of chloroplast increased from the leaf stalk to the leaf tip and attempted to make inferences to explain this observation. He explained:

The leaf stalk close to the stem receives less light because of its position. This leads to less photosynthesis there compared with the leaf. I reckon that is the reason the leaf stalk has less chloroplasts than the leaf tip (S2305).

Student S2327 also sought to make inferences to explain what he observed. He requested the teacher give him some liver cells. Through a thorough observation, he found a liver cell has double nuclei. He speculated what they could be for. He said:

I reckon the reason is that some of the liver cells didn't divide into two after replication, which leads to one cell possibly having double nuclei. We know liver has the potential to be reborn. If the liver is damaged, the cell with double nuclei can divide without any delay. In that way, the liver cell can skip prophase and metaphase to speed the cell division and help the liver recover sooner (S2327).

Students attempting to connect their observations with their background knowledge to make a reasonable interpretation had not been seen by the teacher in previous observation activities.

Students employed investigation outcomes as evidence to draw conclusions

In Task 2, the students found grapefruit contained the least amount of sugar and watermelon the most. Apart from the test for sugar, the students also considered that there might be another factor - starch in fruit, which also supplied energy. For example:

We considered that there might be starch in fruit and it indeed influenced our outcome (2504)

They supposed there was starch in both the flesh and juice of fruit, therefore they added saliva to hydrolyse it. However, they could not detect an obvious colour change in fruit flesh with saliva compared with the control group. One student suggested doing another experiment to test for the existence of starch. They added iodine solution to the flesh of the fruit. This demonstrated there was starch in watermelon but not in the other fruits. The sugar and starch test supported that watermelon contains the most carbohydrate and grapefruit the least. These findings enabled them to conclude, ‘Grapefruit is the best choice for Mary and watermelon the worst’ (Group 2 in Room 25) thereby showing that these students at least were able to use their outcomes to make a reasonable interpretation.

Students constructed knowledge through cooperation

An agreement reached by all groups was that the pork liver had the highest catalase activity of the four samples in Task 3. However, two out of five groups in Room 25 found an abnormal phenomenon. When the students boiled the pork liver up to around 80°C, there was still a significant amount of oxygen generated. This phenomenon initiated enthusiastic student discussions. Student S2504 speculated that catalase might still be active at high temperatures (normally, enzyme lose activity over 42°C). The other students disagreed with her because, from the point of view of evolution, there was no need for the catalase of pork liver to be active when it was heated up to 80°C. Student S2537 attempted to use his chemistry knowledge to explain why oxygen was generated at such a high temperature. He inferred that it was because the metal ions in pork liver react with H₂O₂ to generate O₂. In his words:

I think not only catalase can react with H₂O₂. Some metal ions in the pork liver like Ferro-ion might react with H₂O₂ to generate O₂. I reckon the factor, which keeps the reaction proceeding at 80°C, is Ferro-ion instead of enzyme (S2537).

Student 2509 echoed this point of view and suggested:

We should measure the amount of oxygen produced under normal temperature, then deduct that amount of oxygen after catalase has lost its activity.

Another group of students proposed that a high temperature might lead to the decomposition of H₂O₂ and the production of O₂. They provided their own experience to support this reason.

S2530: We could add H_2O_2 to the pork liver when it was boiled thoroughly. Maybe the high temperature of the pork liver promotes H_2O_2 releasing oxygen straightaway, but not catalase.

T: How could you verify whether your interpretation is reasonable?

S2530: When we cool down the boiled pork liver then add H_2O_2 to it, there is no oxygen released.

Although many of the student interpretations initially sounded reasonable, after a class discussion, the students reached a consensus in support of the interpretation that student S2537 had proposed. The consensus was ‘the factor, which promotes the reaction proceeding at 80°C, is Ferro-ion instead of enzyme’. Their interest in this issue was such that they discussed this with their chemistry teacher in class time.

Students made their learning meaningful

The intervention students tended to do more than simply getting a result. They attempted to explain it and make it meaningful. For example, the fourth group of students in Room 25 accidentally found that the outer part of carrots, cucumbers and potatoes contained the most catalase; and, the inner part of them had the least. They speculated that the inner part of a vegetable was normally for storing nutrients and had fewer metabolic reactions than the outer part therefore there would be more catalase in the outer part of a vegetable.

We found the outer part of carrot, potato and cucumber had high proportion catalase, but the inner part had very little catalase. Maybe there was too much starch in the inner part; hence, catalase was not active.

It appeared that the students tried to make their findings meaningful rather than only present raw data.

In doing an observation activity, if the teacher allows the students little autonomy, their observational outcomes will be restricted to what the teacher demands. In the closed experiments of a leaf of Elodea the students were required to sketch the shape of the Elodea cell and point out the structure of the cell. The students just made sure these things were done. However, in the open investigations the students decided what they are going to observe and therefore they had more fruitful outcomes as shown in Section 9.2.3. This was active learning rather than being told what to do.

To review, students put forward their ideas, defended them and eventually reached consensuses through negotiation in the classroom context. They demonstrated their conceptual and procedural understanding, investigative and social skills and attitude development at the planning, gathering data and drawing conclusion stages of the investigations in a manner consistent with the five principles of the intervention design and the senior high school biology curriculum. The data suggests the feasibility of open investigations in senior high biology in Taiwan.

9.3 Student perceptions of their learning in open investigations

At the end of each task, the students were asked to evaluate what they liked in the investigation, their performance, their learning outcomes and their confidence. This information helped the researcher to understand their perception of the investigations and provided insights the effect of the investigations. Seventy-four students participated in Tasks 1 and 2, and 72 in Task 3. There were 62 evaluation sheets handed in for Task 1, 59 for Task 2, and 55 for Task 3, a total of 176. This is a return rate of 84%, 80% and 76%, respectively. The purpose of the evaluation of confidence was to examine the intervention student confidence in confronting challenging tasks and to determine whether doing the investigations had an impact on their confidence.

9.3.1 What students liked in the investigations

The 74 intervention students were asked what they liked about the investigation and their reasons. There were a total of 176 responses over the three tasks. Thirty percent of the 176 responses left this question as blank.

The students raised six points about the three tasks. These were the affective aspects, autonomy, more learning, relevance to daily life, having discussions and enhancing their ability to think and organise (Table 9.6).

Liked in the three tasks	Percentage (%) (N=176)
Supportive atmosphere for learning and interesting tasks	36
Autonomy	24
More learning	14
Relevance to daily life	7
Having discussions	6
Enhancing the ability to think and organise	5
No likes stated	26
No specific point	4

Table 9.6: What students liked in the three tasks

[N= 62 (Task1) + 59 (Task2) + 55 (Task3) =176]

Sixty-four students (36%) liked the atmosphere of laboratory, which was lively, unrestrained, helpful for learning and supportive of student involvement. Also, they felt the tasks were interesting. One student explained why he liked the atmosphere:

Laboratory work was very lively and I felt less pressured (S2309).

We encountered the problem of collecting gas, but we had a better way after discussing it with the teacher. I like the feeling of discussing problems with the teacher (2503).

They were impressed by peers' genuine involvement.

Everyone was concentrated on doing investigation (S2534).

They indicated that the tasks were interesting because they were challenging and fun. The activities involved using their hands and mind at the same time, rather than only involving manipulation. Also, the tasks were novel to them, which made them more interesting.

This was the first time I experienced the joy of doing an investigation in senior high school, because we had to design and do it by ourselves (S2514).

It appeared that they appreciated and enjoyed the open investigations.

Forty-two students (24%) praised the autonomy they had within the investigations. They had the freedom to make decisions in selecting sample and approaches, and in carrying out the investigation and interpreting results. For example, one student commented on being able to observe cells they had brought to class.

I could observe the cells I brought (S2505).

Others noted that different approaches and data interpretations were possible. Two representative comments were:

We thought up many ways to collect the gas (S2329).

I can use different angles to deal with my data (S2504).

Twenty-five students (14%) considered the tasks offered many opportunities to learn in ways that promoted their understanding. Activities using both hands and mind led students to be more involved and helped develop their competence.

By doing the investigation in person I can sooner find the concepts I don't really understand (S2335).

The other reasons attracted little comment and are not discussed here.

To sum up, the students appreciated the supportive atmosphere for learning and the autonomy they experienced when working on the investigations. They not only enjoyed doing the open investigation but also considered they developed a better understanding of biological concepts than they did in previous closed experiments through their involvement in them.

9.3.2 Student evaluation of their performances

The students were asked to evaluate how well they thought they carried out the investigations. Their responses about the work they were proud of and what could be improved are discussed below.

Pride in their work in Task 1, Task 2 and Task 3

Students were proud of their performance in Task 1 (48%), Task 2 (71%) and Task 3 (60%). Each student might be proud of his/her performance in more than one task. The reasons they gave were; doing well, knowing what they were doing

and how to do it, cooperating with each other, and being more serious and independent. The reasons they gave are listed in Table 9.7.

Reasons for being proud of their performance	Percentage (%)		
	Task 1 (48%) (N=62)	Task 2 (71%) (N=59)	Task 3 (60%) (N=55)
Doing well	11	53	15
Knowing what to do and how to do it	19	10	15
Cooperating with each others	0	10	15
Having a serious attitude	10	2	9
Being independent	8	2	5

Table 9.7: Student reasons for being proud of their performance

More students thought they had done well in Task 2 (53%) than in Tasks 1 (11%) and 3 (15%). In Task 2, the reasons students gave included: accomplishing the investigation successfully; preparing a detailed plan and proceeding as they had planned; positive feedback from the biology teacher; working effectively; and, defending their own argument successfully. Representative comments were:

The teacher helped me to revise the independent variable, so I succeeded at last. I had a sense of achievement (S2322).

We had a great debate. If someone wants to argue, he/she needs to raise a reasonable interpretation (S2504).

Students were proud because they knew what they were doing and how to do it in Tasks 1(19%), 2 (10%) and 3 (15%). These students were confident they had sufficient ability to use the microscope, design and carry out investigations, and apply learning outcomes to everyday life. Two of them commented with confidence:

I knew clearly what I was doing (S2506).

Finally, we can design an investigation and not be afraid of facing unexpected problems (S2506).

There was no special emphasis on cooperation in Task 1 (0%). In Tasks 2 (10%) and 3 (15%), some students took pride in their group distributing work, planning

discussions and drawing conclusions during the investigative process. One student explained:

We had many questions at first and we spent lots of time in discussing how to design the investigation. Although we spent most time in discussion, we perceived that discussions made the investigations simpler, faster and more precise (S2320).

According to Table 9.7, it seems that students had more pride in their performance in the more open tasks (Tasks 2 and 3) than in the less open Task 1.

Suggestions for how to improve performance

Students proposed some factors that needed to be improved in their performance in each of Tasks 1 (56%), 2 (75%) and 3 (60%). These aspects were; time management, experimental techniques, preparation before doing investigations, and attitudes towards doing investigations (see Table 9.8 below).

Aspects that should be improved	Percentage %		
	Task 1 (56%) (N=62)	Task 2 (75%) (N=59)	Task 3 (60%) (N=55)
Time management	26	17	9
Experimental techniques	24	12	24
Preparation of planning investigations	3	40	20
Inattentive attitude towards doing investigations	13	2	5
Others	2	0	2

Table 9.8: Aspects students thought should be improved.

More students in Task 1 (26%) felt their time management needed to be improved than in Tasks 2 (17%) and 3 (9%). In the first task, nearly a quarter of students thought they did not effectively allocate their time to the different parts of the task including determining the direction, dealing with the samples and setting up experimental devices. For example:

I didn't control time well. In the beginning I don't know what to do. It wasted a lot of time (S2319).

We spent much time on discussing how to collect gas, so we left insufficient time to do the investigation (S2529).

More students in Tasks 1 (24%) and 3 (24%) felt their techniques needed to be improved than did the students in Task 2 (12%). Task 2 only required the students to put samples and Benedict's solution in beakers and heat these, consequently it involved fewer problems in manipulating equipment. Students stated they were unfamiliar with the microscope (Task 1) and had difficulty in setting the device for collecting gas (Task 3). In their words:

I am not familiar with the microscope and need to learn to handle it earlier (S2312).

We spent a lot of time on collecting gas first using a flask and then a syringe because of gas leaks (S2503).

Especially after Task 2 (40%), students admitted they were not effectively prepared before doing the investigation because they lacked experience with planning investigations. This was the first open investigation they had needed to complete on their own. There was little need for preparation in Task 1 (3%) because it was an observation activity. In Task 2, the necessary preparation included thought in the planning of investigations and task allocation. For example:

We can't just do the investigation without thinking. It is very important that it is designed before we do it (S2320).

Their degree of self-dissatisfaction declined with more experience as can be seen by comparing the percentages of Task 2 and Task 3 in Table 9.8.

Inattentive attitude had a low percentage.

9.3.3 Student evaluation of their learning outcomes

The students were asked to evaluate what they thought they had learned from doing the investigations. These outcomes comprised cognitive gain, investigative skills, manipulation techniques, experience and attitudes (see Table 9.9 below).

Learning outcomes	Percentage %		
	Task 1 (N=62)	Task 2 (N=59)	Task 3 (N=55)
Cognitive gains	33	30	48
Investigative and social skills	44	60	26
Manipulating techniques	46	14	24
Experiences	3	10	11
Attitudes	18	5	9

Table 9.9: Student evaluation of their learning outcomes

Cognitive gains were identified by a third of the students in Task 1 (33%) and Task 2 (30%) and nearly a half in Task 3 (48%). These gains included enhanced understanding of biology concepts, and linking between practice and theory. Students stated that some abstract concepts became real to them and some alternative conceptions they held were corrected. For example, enzymes had been thought of as the most abstract concept to students (see Section 5.4.1) but through Task 3 enzymes became concrete to them. For example:

I understand more about catalase. It is a type of enzyme and influenced by temperature (2506).

In Task 1, student alternative conceptions were: red blood cells in all types of animal have no nuclei; the inside part of a plant cell is static; and, all plant cells have a regular arrangement. However, they changed these with new concepts as a consequence of the observation. For instance:

I found that the chloroplasts are movable in the Elodea leaf (2326).

Other concepts the students identified as right were: red blood cells have no nuclei in mammal rather than all types of animal; and, not all plant cells have regular shapes. Students modified their conceptions towards those of biologist concepts, a positive cognitive learning outcome.

Students considered they learned how to link practice and theory, especially in Task 2 because it was strongly linked to life real applications. A representative comment was:

Grapefruit is the best choice for me because I am on a diet (2316).

The students reported they had learned investigative and social skills by doing each of the tasks. In Task 2 nearly two thirds (60%) said this was the case. Nearly half (44%) and a quarter (26%) reported this was the case in Tasks 1 and 3 respectively. Some of the skills mentioned were how to design, observe, manipulate, analyse, judge, organise, discuss and reach a consensus. For example:

I learned how to make a detailed plan and to judge some phenomenon (S2320).

Designing an investigation, controlling variables and setting a control group took their special attention. One representative comment was:

I learned how to make hypothesis and consider different factors (2504).

The development of manipulating skills was most evident in Task 1 (46%). This task required the manipulation of the microscope. The percentages for Tasks 2 and 3 were 14% and 24% respectively. The students stated that they became more familiar with the microscope (Task 1) and well collecting gas by syringe (Task 3) and the processing of samples (Task 2). For example:

I use the microscope to find objects correctly and quickly (S2325).

Also students perceived that the tasks provided them with experience in the design and time management of investigations. Moreover, in terms of attitudes they appreciated the importance of patience, persistence and team work.

Around two thirds of the students indicated they gained most in the aspect of investigative and social skills in Task 2. About half agreed they learned most in the cognitive aspects in Task 3 and manipulation in Task 1. Further student quantitative learning outcomes and their comparison with the traditional class of students will be analysed in Section 9.4.2.

9.3.4 Student confidence

Before and after the conduct of the investigations, the intervention students were asked to fill in the Confidence Questionnaire (For scoring method see Section 4.4.2) to evaluate their confidence change during the intervention. There were 14 statements with respect to their ability to do open investigations in the questionnaire. Sixty-seven students completed the identical questionnaire twice.

The student marks in the Confidence Questionnaire for the pre- and post-investigation were analysed statistically (paired t-test). The results indicated there was a gain for all the fourteen items and a significant difference ($p < 0.001$) in the increase of marks for the pre- and post-intervention. The student declared confidence scores for the pre- and post-intervention and their differences are shown in Table 9.10.

Statement	Pre-score	Post-score	Difference
I can make hypotheses (predictions).	2.73	3.16	0.43
I can do an investigation where there is more than one changing factor.	2.49	2.87	0.38
I can make decisions about how many animals or plants to use when I am doing an investigation.	2.73	3.00	0.27
I can make decisions about how many times to repeat an experiment.	2.87	3.13	0.26
I can select appropriate equipment to carry out an experiment.	2.78	3.22	0.44
I can take measurements using appropriate measuring devices.	2.87	3.28	0.41
I can identify the sources of error in my experimental method.	2.51	2.87	0.36
I can present data in an appropriate form.	2.70	3.00	0.30
I can analyse data.	2.77	3.03	0.26
I can make conclusions.	2.75	3.07	0.32
I can justify my conclusions.	<i>2.37</i>	<i>2.70</i>	0.33
I can use appropriate language and layout when presenting what I have found out.	2.66	3.01	0.35
I can re-design experiments when my first results are unconvincing.	2.67	2.88	0.21
I can say when it is appropriate to apply what I have found out to other situations.	2.82	2.99	<i>0.17</i>

Table 9.10: Student declared confidence scores for the pre- and post- intervention and their difference (N=67) (paired t-test, $p < 0.001$).

Key: (1) **Bold:** the highest score in the column;
 (2) *Italic:* the lowest score in the column.

After conducting the open investigations, the student average scores of confidence in all 14 statements all increased. Before the intervention, the most favoured confidence statements were *decide the replication of experiments* and *use appropriate measuring devices to take measurements* (group mean 2.87). The statement with which they expressed least confidence was *justify their conclusion* (group mean 2.37). After the five-week intervention, the greatest declared confidence was with *use appropriate measuring devices to take measurements* (group mean 3.28). However, the group mean scores were higher in post-intervention. Comparing the scores pre- and post-intervention, the student declared confidence with the greatest difference was *select appropriate equipment to do an experiment* (group mean difference 0.44), and the smallest difference was *apply findings to other situations* (group mean difference 0.17). On average, no lessening of confidence was declared by the students.

To gain a clearer picture of the student confidence change, the percentages of the students who increased their confidence, maintained the same level of confidence and dropped in confidence are displayed in Table 9.11.

Statement	Students increasing confidence (%)	Students maintaining confidence (%)	Students dropping in confidence (%)
I can make hypotheses (predictions).	49	40	11
I can do an investigation where there is more than one changing factor.	42	49	9
I can make decisions about how many animals or plants to use when I am doing an investigation.	45	31	24
I can make decisions about how many times to repeat an experiment.	39	45	16
I can select appropriate equipment to carry out an experiment.	52	37	11
I can take measurements using appropriate measuring devices.	49	42	9
I can identify the sources of error in my experimental method.	42	46	12
I can present data in an appropriate form.	40	43	17
I can analyse data.	34	51	15
I can make conclusions.	39	48	13
I can justify my conclusions.	39	46	15
I can use appropriate language and layout when presenting what I have found out.	43	42	15
I can re-design experiments when my first results are unconvincing.	34	45	21
I can say when it is appropriate to apply what I have found out to other situations.	28	57	15

Table 9.11: The percentage of the students who increased their confidence, maintained the same confidence scores and dropped in confidence.

Around half of the students increased their confidence in *selecting appropriate equipment* (52%), *using equipment to make measures* (49%) and *making hypotheses* (49%). It is worth mentioning that about half of the students declared

that their confidence in making hypotheses increased. Making hypotheses is often ignored in closed experiments (see Section 5.6.2) and it is not required in the Taiwan senior biology lab manual; however it is crucial in initiating an open investigation. The proportion of student whose confidence rose in aspects relevant to higher-order thinking, such as *doing the investigation with more than one variable, identifying the sources of error from their experimental methods, presenting data appropriately, making and justifying conclusions and using appropriate language and layout in presentation* was around two fifths. The percentage of student whose confidence increased was lower for *analysing the data, redesigning experiments and applying finding*. This suggests either these aspects might be particularly challenging for students and implies they may need further guidance in these aspects.

Less than a sixth of the students (between 9-17%) said their confidence had dropped in all options listed with the exception of *deciding the amount of animal or plant material used and redesigning experiments when their first results were unconvincing*. Around a quarter (24% and 21% respectively) of students said their confidence had dropped in these two aspects.

It appears that student confidence in some of the higher-order thinking aspects could increase through doing open investigations.

To summarize this section, students declared they gained in their understanding of biology concepts, developed their thinking and better linked practice and theory. They also perceived their investigative skills in thinking, social skills and attitudes, especially in confidence had improved. The student comments suggest that open investigations can have fruitful learning outcomes for students.

9.4 Student comparison of closed experiments and open investigations

To understand student thoughts about closed experiments and open investigations in 2001, two sources of data were collected. The first part of this section details how 70 intervention students viewed closed experiments compared with open

investigations. It includes their responses to the Self-Evaluation Sheets in Tasks 1, 2 and 3. The second part of this section is the comparison of 195 traditional and 70 intervention student views about current experiments/investigations. It sets out responses to the Questionnaires 2B1 and 2B2.

9.4.1 Intervention students compared their experiences with closed experiments and open investigations

Seventy interview students were asked about the differences between their experience of closed experiments and the intervention open investigations. Their responses are discussed below.

Learning

Most students (40%) noted that the open investigations, unlike the closed experiments they had done previously, did not include detailed instructions or have predictable outcomes, so they had to take responsibility for designing the investigation. One student explained their responsibilities thus:

We need to design the investigation by ourselves including proposing an hypothesis and considering the variables (2330).

When they encountered problems, students said they had to think up ways to solve them.

We tried different ways to collect gas (2329).

They had to develop their own conclusions. For example:

We have to make conclusions by ourselves through discussions (2313).

Some students perceived that compared with closed experiments, open investigations helped them develop real understanding of the investigations they were doing. One student explained:

I have done Task 2 before, but I didn't know why we did it and what we did it. Now I completely understand because I am involved with the planning and performing (S2512).

Complexity

Forty-two students (34%) proclaimed closed experiments were simple and easy. In contrast, open investigations were said to have complicated samples, diverse approaches and outcomes and be difficult. For instance:

The current investigation is more complicated. In junior high school we used glucose and starch which are simple solutions. Now we use different fruit juices, which are not easy to be tested (S2335).

The students said that sometimes they had problems in the beginning of an investigation when there were no detailed instructions. In this case they needed to think through how to carry out a task, which was not necessary for closed experiments. Consequently, they thought investigations were complicated and could be messy.

Too many factors need to be considered and I do not know how to start. The investigations are messy (S2517).

The open investigations, although more difficult than closed experiments, stimulated student thinking. As one student explained:

Investigations are difficult but they provide us with more space to think (S2323).

Autonomy

Thirty-three students (19%) recognised they had the freedom to decide what and how to do their task. They appreciated being allowed more autonomy.

We can decide what equipment and methods we want to use. We were not restricted to limited ways (S2522).

The other differences are not discussed because of low response.

9.4.2 Traditional and intervention students comparing their current experiments/ investigations

The students who performed the closed experiments and those who did the open investigations were invited to provide their views about the investigations they did. Three questions were posed about the cognitive aspects of their experience. The two groups' responses are statistically compared in Table 9.12.

Questions	Agree % IS (TS)
1. Some concepts were learned from these investigations.	90(81)*
2. These investigations were related to my daily life.	80(55)***
3. These investigations stimulated my thinking.	83(56)***

Table 9.12: The responses relevant to the cognitive aspects from the intervention and traditional students ($N_{IS}=70$, $N_{TS}=195$).

Key: (1) $p < 0.05^*$, $p < 0.01^{**}$, $p < 0.005^{***}$ (Mann-Whitney U test);

(2) IS: intervention students responding to survey;

TS: traditional students responding to survey.

Four fifths of the intervention students acknowledged that the investigations were related to their daily life (80%) and provided opportunities for them to think (83%). In contrast, about half of the traditional students agreed with these two statements (55% and 56% respectively). Statistical analysis revealed there were significant differences between these two groups in these two statements (both were $p < 0.005$). Ninety percent of intervention group agreed that they had learned some concepts from these investigations, but fewer of the traditional group (81%) considered they learned some concepts. This also had significant differences statistically ($p < 0.05$). Closed experiments had been criticised as being irrelevant to daily life and providing little chance to think (see Table 5.6; Chapter 5) by the students in the survey in 1999. The statistical evidence in Table 9.12 indicates that, on the contrary, open investigations closely linked the investigations to their daily life and stimulated their thinking, which echoed the fourth principle of the original intervention design (see Section 7-2) and also the second common goal of senior high school biology curriculum *explore the basic knowledge of life science and establish the views of modern life science to solve the problems encountered in daily life*.

The students were asked to respond to eight questions related to the processes and skills involved in carrying out an investigation (Table 9.13).

Questions	Agree % IS (TS)
1. My teacher didn't provide me with sufficient cues in doing investigations.	39(12)***
2. I have to apply what I have learned in order to undertake the investigations.	96(72)***
3. The investigations enhanced my ability to design an investigation.	89(49)***
4. The investigations enhanced my ability to interpret data.	87(56)***
5. The investigations assisted me to understand how scientists work.	87(53)***
6. I will transfer the skills I learned from the investigations to my daily life.	62(47)*
7. I learned only manipulation skills from the investigations.	20(14)
8. I need to discuss and negotiate with my group members to accomplish the investigations.	58(50)

Table 9.13: The responses relevant to the process and skills from the intervention and traditional students ($N_{IS}=70$, $N_{TS}=195$).

Thirty-nine percent of the intervention students agreed that their teacher did not provide sufficient cues. However, only 12% of traditional students echoed this view, probably because in closed experiments the teacher provided most of the information the students needed. Almost all the intervention students (96%) felt they had to apply their prior knowledge in order to undertake the investigations. Fewer of the traditional students (72%) had the same view. Most of the intervention students thought the investigations enhanced their ability to design (89%) and interpret data (87%). A smaller percentage of the traditional students (49% and 56% respectively) agreed with those points. Meanwhile, 87% of the intervention students agreed that the investigations helped them to understand how scientists work, compared with 53% of the traditional students. There were significant differences in the two groups' responses to these five statements ($p < 0.005$). More intervention students (62%) than traditional students (47%) were in agreement that they would transfer the skills they had learned to their daily life. The differences of the two groups were statistically significant ($p < 0.05$).

More intervention students (20%) than traditional students (14%) agreed that they had learned manipulation skills from the investigations. More intervention students (58%) than traditional students (50%) considered they needed to discuss and negotiate with their group members to accomplish investigations. However, there were no significant differences in these two statements between the two groups.

The results indicate that students considered they needed to apply their previous knowledge and take more responsibility for their learning when doing investigations. The investigations provided students with opportunities to enhance their investigative skills such as designing and interpreting, which are consistent with the goals listed in the senior high school biology curriculum. The traditional experiments provided the students with fewer opportunities to understand how real scientists work (see Table 9.13). Combined with the findings that intervention students considered they learned more concepts than the traditional students (see Table 9.12), the findings demonstrate that open investigations emphasize both learning process (investigative and social skills) and product (biology concepts). This conforms to the third principle of intervention design (see Section 7.2).

The students were asked nine questions relevant to the affective aspects of their learning experience (Table 9.14).

Questions	Agree % IS (TS)
1. These investigations encouraged my creativity and initiative.	86(50)***
2. These investigations increased my confidence in doing investigations.	72(46)***
3. These investigations are challenging tasks for me.	73(45)***
4. I am satisfied with the current experiment classes.	69(37)***
5. I feel these investigations are interesting.	73(62)*
6. I am depressed about my experimental results.	51(33)*
7. These investigations are worthwhile.	75(63)*
8. These investigations are very difficult for me.	10(13)

Table 9.14: The responses relevant to the affective aspects of learning from the intervention and traditional students ($N_{IS}=70$, $N_{TS}=195$)

The investigations were thought to encourage creativity and initiative by a higher proportion of the intervention students (86%) than the traditional students (50%). Also they increased the confidence of intervention students (72%) more than that of the traditional students (46%). More intervention students (73%) regarded the investigations as challenging than did traditional students (45%). Sixty-nine percent of the intervention students were satisfied with the current open investigation. However, only 37% of traditional students were satisfied with their experiment classes. Statistically, there were very significant differences ($p < 0.005$) between the two groups in the above four statements.

More intervention students (73%) than traditional students (62%) felt that the investigations were interesting. When they saw the outcome of their investigation, more intervention students (51%) felt disappointed than the traditional students (33%). This is not surprising because traditional students were likely to get the expected results if they followed the standard procedures. However, the intervention students were doing unprescribed investigations. They were more likely to get different results, which could make their depression. More intervention students (75%) regarded the investigations as worthwhile than did the traditional students (63%). These differences are significant in statistical analysis at the level $p=0.05$.

Ten and thirteen percent of the intervention and traditional students respectively found the investigations were difficult. There was no significant difference statistically in this item.

There were only 39% of the students in 1999 survey (N=485) who were satisfied with their experiment classes. The degree of satisfaction is similar to the students doing closed experiments in 2001 (37%). Compared with the students who were doing closed experiments in 1999 and 2001, the evidence indicates the students who experienced the open investigations had more positive affective outcomes, and a higher degree of satisfaction with their laboratory work (69%). Data also show that student attitudes toward learning biology, e.g. confidence and interest, were improved. These affective outcomes achieved the goal of the senior high school biology curriculum *cultivate student interests in life science* (see Section 1.3). In short, the open investigations promoted student learning of concepts and

applications, were found to be more relevant to their daily life, to provide students with more thinking opportunities, to enable them to become more independent, to enhance their investigative skills, to help them to experience elements of scientists' work, and facilitate their attitude development. The intervention students had greater satisfaction with the investigations than the traditional students. The outcomes of these investigations show that the open investigations are consistent with the five principles of the intervention design and match the goal of the senior high school biology curriculum.

9.5 Summary of the evaluations of the open investigations

In the intervention, the students demonstrated the ability to make hypotheses, consider factors (identify the variables) and take required measurements. They developed their own design and employed diverse abilities, such as social and investigative skills, to execute the investigation albeit with teacher guidance. In the observation activity (Task 1), their descriptions of objectives were fruitful and their comparisons between the cells were thoughtful. The students also demonstrated their ability to infer, even in an observation activity. They employed experimental outcomes as evidence to draw conclusions and convince other students. Finally, they reached consensus through negotiation. Students developed conceptual and procedural understanding and attitudes toward learning biology through doing investigations. They constructed biological knowledge through interactions with the teacher, peers and the laboratory setting.

The students appreciated the supportive atmosphere for learning and the autonomy they were allowed when doing open investigations. They not only enjoyed doing the open investigation, but also developed more genuine understanding of biological concepts. Data show that more experience apparently helped students to become accustomed to more open work, leading to more expertise in carrying on open investigations. The student average scores of confidence in the fourteen statements of the Confidence Questionnaire all showed a statistically significant increase. This indicated that through open investigations, the student considered their confidence in some aspects related to higher level thinking could increase. Nevertheless, the survey outcomes indicated the students

may have needed further guidance in redesigning experiments and applying findings.

Intervention students perceived their previous experiments had been simple and easy because they had been supplied with procedures and predetermined outcomes. They relied on instruction and had little autonomy and involvement. Conversely, they found the more open intervention investigations complicated and difficult. Despite this, they appreciated having more autonomy and were more genuinely involved. They considered the open investigations stimulated their thinking. Student thought that they need to apply their previous knowledge and take more responsibility for their learning is consistent with a social constructivist view of learning. The evidence provided here indicates that open investigations facilitated student cognitive development, enabled them to be more independent, enhanced their investigative skills, and helped the students to experience real science, while promoting positive attitudes. The intervention students expressed greater satisfaction with the open investigations than the traditional students did with the closed experiments. Based on the outcomes of this study, the impact of the open investigations was generally consistent with the five principles of the teaching design and a match with the goals of the senior high school biology curriculum in Taiwan.

Chapter 10

Discussions, conclusions and implications

The interactive teaching tallying with the open-ended investigations, really improved our learning (S2539).

10.1 Introduction

This is believed to be one of the first pieces of research in Taiwan that has reported student biology learning, including open investigations, in senior high school. This research, using an interpretive paradigm, set out to understand and improve senior high school student learning of biology in Taiwan. Student and teacher views of the existing biology teaching and learning indicated that both of them thought the biology teaching and learning needed to be changed (see Chapters 5 and 6). The design of the intervention in this study (see Chapter 7) drew on this research. The intervention and its implementation were based on a social constructivist view of learning. They took account of Confucian-heritage culture and beliefs and introduced constructivist teaching and learning approaches. Evidence from this study, presented in Chapters 8 and 9, confirms that constructivist-based interactive teaching and open-ended investigations can be effective in developing student learning in senior high biology in Taiwan. Evidence also supports that the constructivist-based intervention matched with the goals of the Taiwanese senior high school biology curriculum. It is hoped that this research will be valuable to senior high school biology teachers in Taiwan and also to researchers who devote themselves to biology education.

This chapter presents the major findings, sets out conclusions and addresses the implications of this study. The major findings, reflecting the four research questions developed in Section 4.1, are elaborated in Section 10.2. The impacts of the study on the researcher who is also the teacher are described in Section 10.3. The implications of and recommendations arising from the study are outlined in Section 10.4. Limitations of the research are explained in Section 10.5. Suggestions for further study are detailed in Section 10.6. Concluding comments are drawn in Section 10.7.

10.2 The main findings of this research

The four research questions for this study were:

- (1) What is the existing learning and teaching situation in biology in senior high school in Taiwan?
- (2) Is interactive teaching feasible in the senior biology classroom in Taiwan?
- (3) Are open investigations feasible in the senior biology laboratory in Taiwan?
- (4) What is the effect of the intervention programme on student conceptual and procedural learning and their attitudes?

These four research questions are discussed under five headings which are the existing teaching and learning situations, the interactive teaching and open investigations, the effects of the intervention programme on student conceptual and procedural learning and attitudes, comparing traditional and intervention student test achievement and satisfaction with traditional and constructivist teaching, and the feasibility of interactive teaching and open investigations in the Taiwanese context of biology teaching and learning.

10.2.1 The existing teaching and learning situation

Both the qualitative and quantitative data set out in Chapters 5 and 6 in this study indicated that the existing situation was that students perceive that teachers use a transmission approach to teaching and conducted experiments that were very closed. This meant that teachers had most of the responsibility for student learning. They consider students learn passively with little thinking of their own. Confucian-heritage culture and views of learning were highlighted to explain this situation. A belief in the importance of examinations provides another explanation for the existing situation for the teaching and learning of biology. This section concludes with an argument for the need to improve the teaching and learning of biology in senior high school in Taiwan.

The belief that the teacher has the main responsibility for student learning

The findings of this study show that the teachers and students believe that the teacher has the main responsibility for student learning. For example, both students and teachers reported it is important that teachers are knowledgeable and prepare supplementary materials for students (see Sections 5.4.3, 5.5 and 6.2.1).

Also, both groups believed that whether students learn depends on how much knowledge teachers can transmit and students can absorb (see Sections 5.3.1, 5.5, 6.2.2 and 6.3.2). Listening to lectures was highly rated as an effective student learning approach in the biology lecture classes (see Sections 5.3.2 and 6.3.2). These findings portray students as passive learners in a manner consistent with research by Aguirre et al. (1990) who also found students viewed themselves as passive. Huang et al. (1998) and Wang et al. (1998) found that in Taiwan teachers are viewed as the ultimate authority and holders of knowledge in a classroom. The findings are also consistent with research that students and teachers believe a teacher's role is simply to present the factual content of scientific knowledge (Tsai, 2003) and that a student's role is to passively receive this knowledge (Tsai, 2003) and so teachers must take most of the responsibility for student learning (Huang, 1997). It is perhaps not unexpected that students and teachers expressed this view of high teacher responsibility for learning because this is congruent with traditional Chinese beliefs about the value of elders, the benefits of learning from experts and the responsibilities of teachers (see Section 2.2). These beliefs support the notion that students are not supposed to play the main role in biology teaching and learning activities, but teachers are. Teacher comments indicated they often felt exhausted under the pressure of the responsibility to do as much as they could for students. They considered that students need to take more responsibility for their own learning (see Section 6.2.1). However, it is hard to expect students to take the main learning responsibility if teachers use a predominately transmission teaching approach because this position students as receivers of knowledge.

The belief in the importance of examination

Teacher and student comments in this study indicate that both groups believe that examinations play a crucial role in student learning. Examinations were said to dominate the teaching and learning of biology. Both the students and teachers reported that they presumed learning and teaching were influenced by student marks (see Sections 5.4.2 and 6.2.2). Salili et al. (2001) also found that teachers made use of marks to monitor student academic learning and that students studied to earn marks.

The content of the examinations in Taiwan is usually based on the content of the textbook, therefore teachers tend to follow these to cover the syllabus (see Section 6.2.1). Meanwhile, examination questions tend to focus on knowledge recall (see Section 5.4.1). The teachers were concerned whether they had taught what they should to prepare their students for tests (see Sections 6.2.1 and 6.2.3). Consequently, transmission teaching was seen by them as efficient for helping students acquire the requisite knowledge to earn marks (see Section 6.2.2). In this context, drill and practice oriented work sheets were common. It seemed that for the interviewed teachers the essence of teaching was to provide students with what they needed to learn to gain good grades in examinations, but not necessarily to teach them how to learn. The emphasis on examinations is not exclusive to Taiwan; it pervades the international education system (Reiss & Tunnicliffe, 1999). However, based on the findings of this research, the Taiwan examination system would seem to be a dominant influence; the teachers reported they hesitated to change the method of instruction because of examination requirements.

Evidence that examinations dominated student learning came from their description of their learning motivation and approaches. The most frequent reason students gave for taking biology was to increase their university entry options (see Section 5.2). An increase in entry options can be seen as an extrinsic motivation for students to take biology. The high value Confucian-heritage culture and beliefs place on academic achievement and university study provides an explanation for this motivation (On, 1996). In addition, the findings are similar to Gow et al. (1996) who found students study subjects to increase their chances of success in the competition for better education. Students taking biology for this purpose were criticized by many of the interview teachers. They commented that students taking biology to increase entry options had low motivation and even disturbed other students because they had no real interest in learning biology. The teachers considered that students who took biology for interest did learn better (see Section 6.3.1). These teacher comments are in line with research that has highlighted that successful learning is closely tied to intrinsic motivation (Hong, Shim, & Chang, 1998), and that students who are intrinsically motivated are more likely to reach their full potential (Karlsson, 1996). Competition, parent and teacher expectations

and external rewards encouraged students to work hard to learn biology and establish their self-worth by outperforming others (Ames & Archer, 1988) in a manner congruent with achievement motivation as described by McInerney (1995) and Pintrich and Schunk (2002) or performance goal orientations by Pintrich et al. (1993). Because of the dominance of questions with set choices, the students believed they needed to memorise answers to earn marks, which led to little thinking (see Section 5.4.1). The teacher also thought students were reluctant to use thinking as a learning strategy (see Section 6.2.1). Student attendance at cram school to practice what they had learned in school (see Section 5.5) was criticized by many teachers who thought this limited student thinking and learning in school (see Section 6.2.1). Students recognized they might answer teacher questions and/or pass tests successfully without knowing the precise meaning of the words in their answers (see Section 5.4.1). Working in Taiwan, Lunetta and Lederman also found that good performance on tests is not necessarily evidence of learning at higher cognitive levels. Menges (1988), Reiss et al. (1999), and Yager and Tweed (1991) have reported similar findings in other contexts. It seems that one right answer examination questions hindered the development of student thinking and genuine understanding (Yang, 1994; Yang & Fraser, 1998), while simultaneously encouraging students to be enthusiastic about memorizing (Hodson, 2002). Both the students and teachers perceived that many of the learning approaches students used were not the approaches they considered helpful (see Sections 5.3.2 and 6.3.2). The learning approaches the students reported they used included *reading the textbook*, *copying summaries from the blackboard* and *using test books and repetitive practice*. Ironically, these approaches were the ones the students said they most disliked (see Section 5.3.2). Research by Gow et al. (1996) also provides evidence that students modify and/or abandon their preferred learning approach if they judge an alternative is more suited to the learning context.

Experiments too closed

Students reported that current teaching approaches did not provide them with opportunities to think, even when doing investigations (see Section 5.6.2). The majority of investigations were prescribed experiments (see Section 5.7.1); the tentative nature of biology knowledge was rarely emphasized. Novak and Gowin

(1984) also found recipe-type investigations disengage students from thinking. Students also experienced lesson content and experiments as generally irrelevant to their everyday lives (see Sections 5.4.3 and 5.6.2), a finding that is also evidence in research by Reiss et al. (1999) and Sandoval (1995). Added to this, students reported that inaccurate experimented results often led to teacher censure due to teacher focus on predetermined results (see Section 5.6.2). This finding is of concern because research suggests that when teachers focus on the correct answer and what should happen, conceptual change rarely takes place (Edmondson & Novak, 1993).

In terms of the data in Section 5.6.1, it appears that the current senior high biology experiments were useful for enhancing skills in manipulating equipment and for coping with tests. This suggests student experience of experiments was as a technical, rather than a cognitive activity. An argument is arising here as to whether students in Taiwanese biology lessons are being provided with the most appropriate teaching contexts for them to achieve effective learning. Taken together, student and teacher dissatisfaction with student learning in biology classes indicated a need to improve the teaching and to investigate it might be improved.

10.2.2 The interactive teaching and open investigations

In an effort to enhance student learning, a learning environment based on social constructivist ideas which not only focused on teaching students what to learn but also on teaching them how to learn, was established in this study. The importance of the learning environment was highlighted by Vygotsky (see Section 3.2.1), and it is also very important from a Confucian-heritage culture viewpoint (see Section 2.2.1). The actual teaching intervention consisted of interactive teaching and open investigation (see Chapter 7). It took into account of Confucian-heritage culture and beliefs (see Chapter 2) whilst drawing on international research (see Chapter 3) and the views of Taiwanese students and teachers (see Chapters 5 and 6). Discussion and real life applications were used to help students enhance their learning, and more open investigations were used to stimulate student thinking. The qualitative and quantitative data gathered during the intervention indicated it had facilitated student learning. In this section, student participation in the social

learning activities of the intervention, their performance of open tasks, their interpersonal relationships within the social learning activities, their beliefs about science, teaching and learning, and their cultural shift within the intervention are reviewed. A case is made that twelfth grade Taiwanese biology students participation in these activities can enhance their learning.

The social learning activities in senior high biology

A social constructivist view of learning underpinned this study. Evidence provided in Sections 8.2 and 9.2 indicates that students cooperatively constructed understanding based on previous experiences whilst participating in interactive teaching and undertaking open investigations. The students used their own language to share their understanding of biology concepts with their teacher and peers through social interactions. They were able to put forward their own ideas, and then persuasively justify and debate ideas by drawing on their prior knowledge and current experiences (see Section 8.4.1). Conclusions were generated through data interpretation and negotiation (see for example Sections 8.2.1 and 9.2.3). Through discussions, student alternative conceptions were uncovered and their thinking and social skills were enhanced. The students learned from each other and they were sharply aware of this. A supportive atmosphere for learning was important and motivating in this (see Section 8.4.1): teacher-student and student-student interactions facilitated the learning process. Discussion is particularly important in investigative work because practical work can illustrate phenomena but cannot explain it. The results of this study show Taiwanese Grade 12 students can negotiate scientifically accepted knowledge with the assistance of a competent peer or the teacher (see Sections 8.2 and 9.2). These findings are reasonable with previous research that indicates an interactive approach can assist the development of concepts in science (Pfundt & Duit, 1994) and that discussion can facilitate the development of deep learning (Biggs, 1987; Brown, 1996). The findings suggest that many of the students had moved towards a more constructivist approach to learning through their social interaction experiences.

Although the intervention teaching emphasized student-centred learning, this is not to downplay the teacher's role. In this study, the teacher used Socratic

teaching approaches and prompt questions to guide student thinking and support understanding. A question-feedback strategy was employed which proved effective in assessing student learning and encouraging student thinking (see Sections 8.2 and 9.2). Prior to the intervention, students had stated they were afraid of being asked questions (see Section 5.4.3) and threatened when a teacher asked for elaboration or challenged their ideas in a follow up to their answer. The findings here suggest that if teacher probing questions becomes a routine practice students realise the teacher has a genuine interest in knowing more about what they think and why, and consequently they become more willing to interact with the teacher (Brooks & Brooks, 1993). Thus, the findings lend support to the significance of teacher's questioning and assistance in supporting student learning (Forman & Cazden, 1985; Hodson & Hodson, 1998).

Shifting the roles of the teacher and student does not contradict Confucian-heritage culture. In the culture, a teacher has a duty to students. This duty does not necessarily need to be interpreted as just the provision of facts. It can involve teaching students thinking skills and how to search information so they can gain knowledge through reasoning and the intergration of information. Also, a student has their duty. This duty is to study hard. However, studying hard does not equate to spending lots of time memorizing facts rather it can be interpreted as learning with understanding. Through social interactions students can construct their meaning and enhance the quality of their learning. In this way, students can fulfil their duty.

Encouraging social interactions in biology classroom provides students with an envionment to facilitate knowledge construction. This conforms to Mencius' idea that children can learn well when adults provide them with an environment for this. It supports the notion that learning is not merely an individual endeavour but also involvd social factors.

Student motivation towards learning and their understanding of biological concepts was promoted when they realised the content was applicable and helpful in their everyday lives. They came to value the learning and showed more enthusiasm towards learning (see Sections 8.3.1, 8.5.3, 9.3.1 and 9.4.2). These

findings support the view that when students find ideas interesting and relevant their learning is meaningful. In contrast, as Howe (1996) found, without application biology concepts can remain abstract and irrelevant to students.

Student performance on open tasks

The nature of the open investigations stimulated student thinking and encouraged them to take more responsibility for their own learning through providing students with more autonomy. The students had successful learning outcomes on progressively more open tasks. In the first instance, a microscope observation activity provided an experience of more open work. Student descriptions of the objects were rich and the comparisons they made between the cells more thoughtful than the non-intervention class. The teacher-student dialogues about the cells focused on different interpretations to engage students in deeper thinking (see Sections 9.2.2 and 9.2.3). The students demonstrated inferential ability by linking their use of appropriate knowledge to frame their observations (see Section 9.2.3). Student responses to the microscope task contrast with those of Jimenez-Aleixandre and Diaz de Bustamante (1997) who found students were copied each others' results and teacher-student interactions revolved around technical issues. They also contrast with the work of Berry et al. (1999) who found little evidence to show students tried to link their observations with prior knowledge. In their case, students viewed the microscope observing activity as a confirmatory activity rather than one that might serve as a platform to establish a pattern of interactive negotiation. In the more open investigations students were able to demonstrate conceptual and procedural understanding in the planning, gathering of data and drawing conclusion in open investigations (see Section 9.2). Most students were able to identify some of the pertinent variables. Added to this, they could point out the importance of each variable in isolation although they had problems in integrating them (see also Lazarowitz and Penso, 1992). Data from student dialogues during the open investigations indicated that individual thoughts could be refined through group discussion about investigations, as was also found by Haigh (1998).

While the students generally enjoyed the investigations, some experienced them as messy and unstructured (see Section 9.4.1). Students found the activities

challenging because, unlike traditional experiments, there was no lab manual to follow and they had to make decisions without knowing whether their ideas were right or wrong. Student comments in Section 9.3.2 suggest more experience with open tasks could help them perform the tasks better and more as scientists do, a finding that conforms with the work of Roth (1995) who also highlighted that personal experience of doing open-ended investigations is crucial. This experience can be messy and inconvenient but eventually profound whilst enabling students to gain a more authentic experience of science.

Interpersonal relationships in social learning activities

In this study, students were placed in groups and asked to work together. Although the groups were not required to nominate a leader one or two students in each group took on leadership responsibility. They distributed work and made conclusions during the investigations. Groups with good leadership tended to have more detailed planning and more reasonable conclusions. Their oral or written reports were more detailed and insightful than groups without competent leadership (see Section 9.2.2). These findings parallel research by Bianchini (1997) and Lemke (1990). Alongside this, most students demonstrated that they were able to build relationships and work cooperatively (see Sections 8.2.4 and 9.2.2). They acknowledged the value of group work and appreciated the benefits of positive social relationships and cooperation (see Sections 8.2.4, 8.3.2, 9.3.1 and 9.3.2). However, not all groups operated in this way, sometimes a small subset of students appeared to regard themselves as infallible. In these groups the atmosphere was not good, very little communication occurred and most members were excluded from the task (see Section 9.2.2). The outcomes of these groups were generally very unsatisfactory, all the more so when compared with those where group members worked together.

The student beliefs about science, teaching and learning

Evidence provided in this study shows that student beliefs about the nature of science are hard to change (see Section 8.5.1). In the intervention class there were students who held different epistemological perspectives ranging from constructivist to more objectivist views of learning. Although most of the students supported the new teaching approach, a minority still expected the teacher to

provide the correct answer at the end of a discussion (see Sections 8.2.1, 8.3.2 and 8.5.3). For these students, it seemed that a correct answer was more important than understanding the process by which an answer is reached. The student quote at the beginning of Chapter 8 suggests that if students believed that biology knowledge was constituted as absolute truths there tended to be fewer possibilities for conceptual modification. However, if they perceived biology knowledge as tentative they might be more likely to accept any adjustments. Data also shows that student epistemological beliefs about science are related to their views of learning and teaching in biology and their acceptance of the constructivist-based teaching (see Sections 8.5.2 and 8.5.3). This difference provides a possible explanation for the influence between student understanding of the nature of biology and their approach to learning. Hogan (1999), reporting on an intervention focusing on the co-construction of knowledge in groups, also noted that this might not be as readily embraced by students who value knowledge transmission.

Cultural shift in the classroom

The findings of this study show that students may find it difficult to move from a structured environment to one where they are expected to accept more responsibility. Transmission and constructivist teaching can be seen to provide different cultural contexts for learning. Most students in this study supported the constructivist teaching approach used in the intervention. Their recommendation was that this approach should be used earlier in their schooling because they needed time to become accustomed to taking a more active part in the learning process. Alongside this, some students felt discussion time was too long. They recommended more time for teacher overall summary and conclusion (with explicit knowledge) (see Section 8.3.3). These student comments suggest that although the students were able to shift time is needed for this.

In conclusion, the intervention based on constructivist principles was conducted with an intention to enculturate the students into the biological science community by actively engaging them in thinking through social interactions. It was designed to include interactive teaching and open investigations. Evidence from the study indicates that Taiwanese biology students can participate in more student-centred

teaching and undertake open investigations although some students struggle to make the adjustments required by the new teaching.

10.2.3 The effects of the intervention programme on student conceptual and procedural learning and attitudes

In the conceptual aspect, student understanding of biological concepts was developed through the intervention (see Sections 8.2 and 9.2). For example, through the argument *whether insulin is an enzyme or hormone* in Lesson 7 and the activity of catalase in Task 3 the students gained a clearer comprehension of the nature of enzymes which had been quite abstract, but now was more real to them. Student ability to apply abstract ideas to concrete situations was facilitated. For instance, within Task 2 students deployed their prior concepts of sugar testing to solve the problem of weight loss in daily life. Nearly all (96 %) of the intervention students declared they needed to apply what they had learned previously to undertake open investigations. This was significantly different from the traditional students (72%) (see Section 9.4.2).

In the process skills aspect, data from this study indicates that the intervention promoted student procedural understanding through enhancing the investigative skills of inference, design, judging and interpreting along with the social skills of communication and cooperation (see Sections 8.2, 8.3, 9.2, 9.3.3 and 9.4). It is worth mentioning that the students interviewed in 1999 perceived there was no need to make an hypothesis in the prescribed experiments they did, this was scientist's work (see Section 5.6.2). However, the intervention students declared this was crucial in initiating an open investigation. The emphasis on investigative and social skills in open investigations is quite different from that in closed experiments where manipulation is the main focus. Student questions and reports supported that their investigative skills were enhanced. The intervention especially the open investigations, provided a learning context which enabled the students to think like scientists and to understand more of the nature of science (Lazarowitz & Tamir, 1994).

In the affective aspect, the intervention enabled the students to become more open-minded, to have greater respect for logic, and to more willingly consider

evidence when drawing conclusions (see Section 9.2). Also, it enabled the students to be more independent and show initiative, stimulated their interest and enhanced their creativity and confidence (see Sections 8.3, 8.4, 9.3.4 and 9.4). Several times, when the students were excited and engaged in a debate, the dismissal bell rang and they ignored it. Their debate continued, something which attracted the attention of students from other classes who watched and listened from outside. According to the researcher-teacher's observations, this involvement increased over the time of the intervention. These findings are consonant with Hazel and Baillie's (1998) study that open-investigations provide students with a good motivational context. The students' enthusiastic attitude not only showed in class time, but also in their written reports. They wrote the reports by themselves and posed many questions. These questions reflected that they had gained a genuine understanding of the investigations.

10.2.4 Comparing the traditional and intervention student test achievement and satisfaction with the traditional and constructivist teaching

The constructivist teaching did not focus on the traditional examination content. Despite intervention student concerns they might have difficulty in preparing for examinations (see Sections 8.3.3 and 8.4.3) the first term examination outcomes were comparable in the traditional and interactive teaching classes. That is, the intervention maintained student learning as demonstrated by evidence from their test performance (see Section 8.6). However, the intervention students expressed greater satisfaction in their learning and the teaching than the students who received traditional biology teaching (see Section 8.4). This raises questions about the approbation of examination results as a measure of student achievement. The research findings show the development of student conceptual and procedural knowledge along with enhanced attitudes which suggests that not all learning might be tested through the traditional examinations.

Three groups of students were surveyed about their satisfaction with their biology classes including theory teaching and investigations. Less than 40% of the students in 1999 were satisfied with their biology classes including the lecture and experiment classes. The quantitative evidence indicates that more of the intervention students (70%) were satisfied with their theory biology classes than

the students who received traditional biology teaching (60%) in 2001. Similarly, more of the intervention students (69%) were satisfied with their open investigations than the students who did closed experiments (37%). Two possible reasons are discussed below.

Firstly, three of four traditional classes in 2001 were taught by the researcher herself and she had taught them since they were eleventh graders. Her teaching in the traditional theory classes was as usual. The teaching emphasized knowledge transmission but life examples were provided and the students were encouraged to ask the teacher questions at the last ten minutes of a lesson but with little peer discussion. She had no intention of going back to the conservative old teaching to manifest the special efficacy of the intervention, which might lead to the high percentage (60%) of satisfaction in traditional theory teaching. However, the teacher provided the same closed experiments as in traditional experiment classes for the traditional group of students. This can be the reason that the percentage of students who were satisfied with the investigation aspect in this group was low (37%).

Secondly, most content of theory teaching is supposed to appear in the school and entrance examination. The teacher provided an organised a set of knowledge for the traditional class of students that matched what would be in the examination. However, during the intervention the intervention students were offered limited facts to be memorized. Although they said they enjoyed the fruitful discussions and constructing meaning by themselves, they worried about the outcome of the test. Responding to the statement, 'I am not sure I can cope with tests by the lecture classes', the percentage of the intervention students and traditional students that agreed with the statement was 66% and 42% respectively (see Section 8.4.3). The intervention students might have had a higher degree of satisfaction with the interactive teaching if they had not been worried about test results. The intervention students were able to enjoy the freedom and autonomy when doing the open investigations because they did not expect this material to be examined.

10.2.5 The feasibility of the interactive teaching and open investigations in senior high school in Taiwan

The findings of this study demonstrate that student learning can be improved through interactive teaching and open investigations in senior high biology in Taiwan (see Sections 8.2 and 9.2). The teaching based on a social constructivist view of learning engaged the students in thinking, increased their involvement and promoted them to take more responsibility for their learning according to the students themselves and the teacher observation (For the evidence, see Sections 8.3, 8.4, 9.3 and 9.4). The development of student cognitive, process skills and affective aspects has been elaborated in Section 10.2.3. A comparison of student perceptions of the old and new teaching indicates that they preferred the intervention teaching (see Sections 8.4 and 9.4). Also, the comparisons of the two groups (traditional and intervention) student satisfaction with the teaching indicated that the intervention students had higher degree of satisfaction (see Section 10.2.4). The increase in intervention student confidence in doing open investigations was statistically significant (see Section 9.3.4). Although the students and teachers in 1999 had questioned student abilities and skills to do open work (see Sections 5.7.1 and 6.4.2), the intervention students demonstrated that they were able and confident in conducting open investigations (see Sections 9.2, 9.3.4 and 9.4). Evidence of student learning (see Sections 8.2 and 9.2), student comments and the outcomes of the student survey (see Sections 8.3, 8.4, 9.3 and 9.4) in the interactive teaching and open investigations indicate the intervention was consistent with the five principles of the teaching design and congruent with the senior high school biology curriculum in Taiwan.

The results of the study support the feasibility of interactive teaching and open investigations and are not in accord with the criticism by Matthews that constructivist teaching is difficult to implement (Matthews, 1994). Since this teaching was conducted successfully with twelfth graders who have the most examination pressure, there is no reason to expect that it would not be successful in other grades. The social constructivist teaching in the interactive teaching and open investigations has been shown to be more effective than traditional teaching in the context of biology learning in Taiwan.

10.2.6 Summary of the findings of this research

Based on a social constructivist view of learning, students do not passively receive knowledge from the teacher rather they construct knowledge based on their prior knowledge and through interaction with others and the physical world. In this study, both the students and teachers were dissatisfied with the existing teaching and learning in biology. The students thought the teaching content and laboratory activities were irrelevant to daily life and the experiments were too closed. Teaching and learning were dominated by examinations. These problematic aspects of the teaching and learning suggested the need for an innovative intervention.

Confucian-heritage culture, in conjunction with students' own views of learning, constituted the social and cultural influence on student learning in senior high biology classes in Taiwan. The intervention was designed as a shift from traditional teaching and learning to a constructivist teaching and learning situation that also took account of cultural beliefs. In the intervention, the teacher used a variety of pedagogical approaches to lead the students to take more responsibility for their own learning. Although student examination performance was same in the traditional and intervention groups, the intervention students enjoyed their lessons more and expressed greater satisfaction with their biology classes. The data of this study indicated that students enhanced their conceptual and procedural understanding and extended their process skills. The study provides evidence that an intervention programme based a social constructivist view of learning, especially the open investigation component, is feasible and can have significant impacts on Taiwanese student learning of biology. In addition, a learning culture shift, albeit small, is possible when students are supported to make the change.

10.3 The impacts of the study on the researcher

Before conducting this study, the researcher was tired of the transmission teaching approach and interested in developing a set of more effective teaching strategies. When she began this study, she found her epistemological perspectives were challenged. Undergoing a succession of frustrations during the process of change, finally, she was convinced by constructivist views of learning. Following that, she

attempted to influence her students, colleagues and her family towards the constructivist assumptions.

The researcher no longer gave first priority to student test results, rather she listened to their voices and became concerned about how students learn. When she understood that her students arrived in classroom with their own views of learning and biological matters, she did not blame them for not understanding her teaching of content. Rather she endeavoured to help them understand biologists' views and expressed her appreciation of student alternative views. As the students experienced what was real more like scientists' work they showed more willingness to learn through thinking and linking what they had learned in biology classes to their daily life. Even though she still employed a transmission teaching approach most of the time, her provision of interesting real life examples and her allowing students the freedom to ask questions about what they were interested in, led to sixty percent of the traditional group of students supporting her lectures.

The intervention programme was a radical activity for the Grade 12 students in Taiwan. In an attempt to decrease their sense of insecurity, the researcher devoted herself in establishing rapport between herself and the students in the intervention classes prior to the commencement of the study. The students were convinced her intention was to help them develop better learning approaches and so they were willing to try alternative teaching approaches. During the conduct of the intervention programme, students often sought out the teacher to discuss their ideas and showed an enthusiastic attitude towards learning biology. This attracted the attention of the researcher's colleagues. Four of them were curious about what they observed and discussed this with the researcher. From then on, these teachers frequently exchange their opinions about student learning with the researcher.

In the beginning, the researcher undertook the research with little support from her family because they thought that doing research would distract her from her family responsibilities. When she discussed with her two boys about their learning, her husband was concerned that this was taking time from their study. The researcher continued to explore constructivist views of learning with her boys. Her first son, Joe, preferred deep learning approaches. However, her second boy,

Robert, tended to avoid challenging tasks and preferred to use surface learning strategies and rote memorization. After three years, Robert was more inclined to prefer thinking and use deep learning approaches. When Joe was asked questions relevant to science by Robert, he tried to use questions to guide Robert into thinking instead of giving him answers. The researcher's two boys gained entry to the top senior boys' high school in Taiwan. Her first son gained entry to a public medical school with good reputation in Taipei. These successes convinced the researcher's parents-in-law and her husband that she might have effective strategies for teaching children; although she considered entry to a top school did not necessarily represent success in education. The researcher's husband also changed. Encouraged by the researcher, he accepted an invitation by a medical school to receive teacher training and conduct PBL (Problem-Based Learning) clinical teaching. Throughout the two years of training and teaching, he became convinced of the value of the new perspective. The researcher cannot anticipate the impact this study will bring for readers however she is quite sure this study changed her life and it was worthwhile doing this research.

10.4 Implications and recommendations

The teaching and learning of existing biology classes in senior high school in Taiwan were not considered satisfactory by participating teachers or students. In contrast, the intervention programme was proved to be effective in improving student learning of biology in senior high school. Based on the findings of this study, implications and suggestions for teaching and learning are drawn.

10.4.1 Implications for teachers, researchers and policy makers

In this section, some implications of this study are set out. The findings of the study indicate that Taiwanese teachers can have some confidence that with careful guidance and suitable opportunities, their students should be able to accept interactive teaching and do open work and develop investigative and social skills while at the same time maintaining examination performance and gaining more satisfaction from and interest in learning biology. Since the social constructivist-based teaching is more welcome to students, this research raises the question of, 'Why do teachers still adhere to traditional teaching?' Confronted by rapid change

in the twenty-first century, teachers need to consider whether old ways of teaching are appropriate to educate our next generation.

To help students in learning biology, teachers need to consider what more social constructivist teaching approaches that can promote student cognitive and process skills, and affective development. However, for most teachers changing their beliefs and habits of teaching towards a more constructivist approach requires a fundamental shift in their basic assumptions about teaching and learning (Kinchin, 2002). A constructivist philosophy is likely to challenge the beliefs of many traditional biology teachers who have objectivist views of biology and Confucian beliefs about the roles of teachers and students. Researchers who attempt to help teachers to change need to think about these beliefs if teachers are not to resist change. Biology teachers in Taiwan need opportunities to consider how they think about teaching and about themselves as a teacher and also to consider how to motivate students to learning. During this process they need to be helped to appreciate that any change, including student change, takes time and students learning more actively involves changes in teacher and student epistemological beliefs.

If traditional teaching is to be replaced by more constructivist-based teaching, assessment also needs to be changed. There is a need to shift the paradigm from a testing model to a broader model of educational assessment. Specifically, to be consistent with the intervention teachers need to use assessment for learning approaches such as student evaluation sheets and question-feedback to replace quizzes. These approaches will help teachers identify student individual differences (e.g. prior learning experience and learning capacities) and are congruent with Chinese thought (see Section 2.2.1). Considering Chinese culture however examinations cannot be ignored. The assessment of deeper thinking and process skills could be developed rather than maintaining a strong focus on knowledge alone. As part of this, Taiwanese educators need to ask whether their goal is to cultivate successful test takers or promote lifelong learners?

10.4.2 Recommendations

Based on the implications of this study, some recommendations for researchers and educators are: teacher education; develop interactive teaching activities for biology teachers; begin with open investigations; and, conduct constructivist-based teaching in all science subjects.

Teacher education

Taiwanese teachers need further education about social constructivism and its implementation to help them prepare for a constructivist-based teaching. If the teachers teach without constructivist theoretical background underpinning, the teaching cannot be expected to be successful (Spillane, 1999). Action research is likely to be more practical than sessions or workshops for the senior high school biology teachers because once a session or workshop is over teachers may not revisit the information presented. If they work with researchers teachers are more likely to receive feedback to sustain changes in practice. In Taiwan, teacher education for the conduct of more constructivist teaching has already begun for junior high school teachers. Hopefully, this can happen for senior high school teachers.

Develop interactive teaching activities for biology teachers

According to the interviewed teachers, well-designed teaching activities would promote their willingness to undertake innovative teaching. Without this support, they would rather retain their traditional teaching approaches because of their convenience and efficiency (see Section 6.4). Therefore, the provision of well-designed teaching activities for theory teaching and open investigation might be helpful for teachers as a strategy to reduce their resistance to change. However, teachers also need to be encouraged to design activities to meet their individual needs and those of their students. In addition to teaching activities, any teaching package would need to include information to help teachers understand the constructivist ideals that underpin the new approach/activities so they feel more confident in their conduct.

Begin with open investigations

Theoretically, interactive teaching should be conducted followed by open investigation. Nevertheless, if teachers who are interested in conducting constructivist teaching are worried about changing both activities at the same time it is suggested they begin with open investigations. The researcher suggests this because the findings of this study indicated more students agreed with less prescribed investigations than interactive theoretical teaching. Moreover, investigations are seldom assessed in the examinations and so are less likely to meet with student resistance. When teachers design open investigations, it is suggested that they begin with ones that are less open and gradually move to more open activities as a strategy to help student confidence and skills.

Conduct constructivist-based teaching in all science subjects

Students indicated that they had problems in shifting between different teaching approaches with different science teachers. To promote a smooth adoption of more active student involvement in teaching and learning, senior biology teachers may need to convince earlier years science teachers to adopt constructivist approaches. Once students become accustomed to learning by thinking, teaching will be able to be conducted more efficiently. According to the need of a teaching context, science teachers co-teaching in terms of learning by stimulating thinking is recommended.

10.5 Limitations of the research

The researcher's status and the senior high school context become the limitations of this research. It was difficult to find senior high school teachers with more constructivist views of learning who were willing and able to conduct the intervention. In an effort to convince others, the researcher as the intervention teacher decided to teach the intervention to the classes of students she was assigned by her school. To reduce possible variables in comparing the effect of traditional teaching and the intervention teaching, she taught three classes in a traditional way and two classes using the intervention. Being both researcher and teacher posed some challenges, taking time to collect student-student dialogues promoted by their learning arising during the lessons might have taken time from

the teaching. Also, as mentioned in Section 10.3, before the commencement of this study, the teacher spent a year establishing rapport between her and the participating students. This may have led them to give more support to her as teacher and provide more positive feedback for the teaching (see Section 10.2.4). Because she had a good relationship with her students, some of the intervention students only commented they sometimes obtained 'uncertain knowledge'. Typically, if this happens, students criticize the teacher as ignorant.

Related to the aspect of school context, three points arose. Firstly, the five weeks of intervention time was the maximum that could be used for an intervention with Grade 12 students. If the time for the intervention had been longer, it might have attracted the special attention of school administrators because these students have to sit university entrance examinations after eight months and the teacher is supposed to do review work with them. Secondly, influenced by the examination culture, students and society places an emphasis on gaining good marks. The researcher was cognizant of the need for the intervention to maintain student standards of achievement and confidence. Lastly, it is possible students had different interpretations of the same question based on their different teaching and learning experiences, which then became a limitation in evaluating student outcomes.

Although the intervention students had much better learning outcomes compared to the traditional group of students, it is acknowledged that their learning context was embedded in the Confucian-heritage culture and still has its implicit restrictions in accepting a non-traditional teaching. Although the intervention might not be radical by some standards, in the context of what students and society expected it was a significant shift. The researcher could not make a greater change because of culture.

10.6 Suggestions for further research

This is the first research in Taiwan which has thoroughly reported student biology learning including the use of open investigation in senior high school. Therefore, this study is able to be a base for further study, which could focus on:

- (1) longitudinal research (tenth to twelfth grade) on the impact of using interactive teaching approaches on senior high school student learning in biology in Taiwan;
- (2) extending the intervention approach that proved successful to working with junior high school students learning in biology in Taiwan;
- (3) the relationship between student epistemological perspectives and their behaviours in the biology classroom; and,
- (4) the assessment of open-ended investigations in the senior high school biology laboratory.

10.7 Concluding comments

This study set out to understand student and teacher perceptions of student learning in biology in senior high school in Taiwan. An intervention was designed to enhance student learning. The data from this study has shown that in Taiwan a teaching intervention based on a social constructivist view of learning can enhance the teaching and learning of senior high biology so that students learn actively, their cognitive development is facilitated, their abilities are enhanced, and they enjoy their lessons more. Teaching and learning is enhanced when the teacher is more aware of how and what students learn and encourages them to take a more active part in lessons. The findings suggest that it would be worthwhile for more teachers to use such a teaching approach. More work is required to develop a greater understanding of the impact of this approach on students and their learning, and how to support teachers in Taiwan to teach in more constructivist way.

Appendix 1

The key objectives and teaching content in senior high school biology

Appendix 1.1: The key objectives and teaching content in Grade 10 in senior high school biology

Grade 10: Basic Biology	
Objectives	Teaching Content
1. To recognize the extent of biodiversity in Biosphere (related to cognition).	1. The interactions in the living world.
2. To understand the status and responsibility of human beings in nature (related to attitudes).	2. Individuals and populations.
3. To appreciate the beauty of nature's harmony, cherish the ecological environment and respect lives (related to attitudes).	3. Communities and ecosystems.
4. To clarify the view of the value of nature conservation (related to attitudes).	4. The life styles and their living environments in the Biosphere.
5. To develop the abilities of collecting, analysing and interpreting information properly (related to process skills).	5. Humans and the Biosphere.

**Appendix 1.2: The key objectives and teaching content in Grade
11 in senior high school biology**

Grade 11: Life Science	
Objectives	Teaching Content
<ol style="list-style-type: none"> 1. To explore the structures and functions of organisms and understand the mystery of lives (related to cognition). 2. To understand the growth process, life maintenance and reproductive ways of organisms (related to cognition). 3. To develop the abilities of observing, reasoning and discerning. Arousing potential of creativity enable students to solve problems by scientific methods (related to process skills). 4. To understand the relationship between life science and human life (related to attitudes). 	<ol style="list-style-type: none"> 1. Cell and organism. 2. The life phenomenon of micro-organism. 3. Plant nutrition. 4. Plant reproduction, growth and development. 5. Animal metabolism and homeostasis. 6. Animal coordination. 7. Animal reproduction and inheritance. 8. Life science and human life.

**Appendix 1.3: The key objectives and teaching content in Grade 12
in senior high school biology**

Grade 12: Biology	
Objectives	Teaching Content
1. To explore the basic principles of life from molecule and cell levels (related to cognition). 2. To understand the content of modern biology and its impact on human life (related to cognition and attitudes). 3. To develop creative thinking to promote student ability in conducting life science research (related to process skills).	1. Organism basic structure and function. 2. The energy of maintaining life phenomenon. 3. Nutrition absorption. 4. Nutrition transportation. 5. Gas homeostasis. 6. The homeostasis of body fluids within the organism. 7. Hormones and coordination. 8. Nervous system and behaviour. 9. Organism response to the stimulation from circumstances. 10. Human immune system. 11. The molecule dominating life mystery. 12. Inheritance. 13. Evolution.

生物科課程標準

高一基礎生物	
重點目標	教材大綱
<ol style="list-style-type: none"> 1.認識生物圈中生物的歧異 2.了解人類在自然界中的地位與 3.欣賞自然和諧之美，愛護生態環境，尊重生命 4.澄清自然保育之價值觀 5.培養資料蒐集、分析，及適當解釋的能力，以了解或解決生態上的問題 	<ol style="list-style-type: none"> 1.生命世界中的交互作用 2.個體與族群 3.群集和生態系 4.生物圈中形形色色的生物及其生活環境 5.人類和生物圈

高二生命科學	
重點目標	教材大綱
<ol style="list-style-type: none"> 1.探討生物體的構造與機能，了解生物的奧秘。 2.了解生物生長的過程、生命維持及延續的方式。 3.培養對事務觀察、推理及思辨的能力，啟發創造潛能，俾使其能以科學方法解決問題。 4.了解生命科學與人生的關係。 	<ol style="list-style-type: none"> 1.細胞與生物體 2.微生物的生命現象 3.植物的營養器官與功能 4.植物的生殖、生長與發育 5.動物的代謝與恆定性 6.動物的協調作用 7.動物的生殖與遺傳 8.生命科學與人生

高三生物	
重點目標	教材大綱
1.由分子與細胞的層次探討生命現象的基本原理 2.了解現代生物學的內涵與其對人類生活的衝擊 3.培養創造性思考，以發展其獨立從事生命科學研究的能力	1. 生物的基本構造與功能 2. 維持生命現象的能量 3. 養分的攝取 4. 物質的運輸 5. 氣體的恒定 6. 生物體內體液的恒定 7. 激素與協調作用 8. 神經系統與行爲 9. 生物對外界刺激的感應 10. 人類的防禦系統

Appendix 2

Student Interview 1 (SI 1)

1. Why are you taking biology?
2. Do you have any difficulties in learning biology?
3. a. How do you prefer to learn biology?
b. Which type of learning is most helpful to you?
4. Are there any opportunities to learn biology outside the lecture classes?
5. What do you think about the current biology lecture classes?
6. Would you like to see changes in the current lecture classes? If so, what changes?
7. Why do you do experiments in learning biology?
8. How do you feel about experiments?
9. What do you learn from experiments?
10. Do you know what you are doing in experiments and how do you know?
11. If your experimental results do not fit the theory, how do you feel?
12. Do you think that biology experiments are useful in your daily life?
13. What are the advantages and disadvantages of the current experiment classes?
14. Would you like to see changes in the current experiment classes?

學生晤談 1

- 1.你爲什麼要選生物學？
- 2.你在學習生物學時，有什麼困難嗎？
- 3.你喜歡以何種方式學生物學？那一種學習方式對你幫助最大？
- 4.除了生物課外，還有什麼機會可以學習生物？
- 5.你對現有的生物理論課看法如何？
- 6.你希望現有的生物理論課有什麼改變嗎？若是，如何改變？
- 7.你學習生物學時，爲什麼要作實驗？
- 8.對於實驗課，你有什麼看法？
- 9.你如何從作實驗中學習？
- 10.作實驗時，你知道你在作什麼嗎？你如何知道？
- 11.如果你的實驗結果與理論不符，你覺得如何？
- 12.你有否此經驗，實驗課所學在你的日常生活中很管用？
- 13.現有的生物實驗課，有何優缺點？
- 14.你希望現有的生物實驗課有什麼改變嗎？若是，如何改變？

Appendix 3

Teacher Interview

1. Why do you think students take biology?
2. Why do you think students should learn biology?
3. What do you think are student attitudes toward learning biology?
4. (1) In what ways do you think the students learn biology? (2) What ways do you think are the most useful? (3) In what way do you teach biology? (4) Which teaching way is most useful to the students learning?
5. Do you have any difficulties in teaching biology?
6. What do you think the students do learn from the biology class?
7. Are you satisfied with the student learning outcomes and academic achievements?
8. What are the reasons for students to carry out experiments when learning biology?
9. Do you think the student learning in the lecture classes is more efficient than in the experiment classes?
10. What are their attitudes toward doing experiments? Are they keen to do experiments?
11. Do you enjoy conducting experiments?
12. If there are no experiment classes to correspond with lecture classes in your teaching, how would you feel?
13. What are the weaknesses and strengths of the current lecture classes and experiment classes?
14. Are there changes you would like to see in the current lecture classes and experiment classes? If yes, what are they?
15. What are your views of interactive teaching and open-ended activities?

教師晤談

1. 你認為學生何以要選生物學？
2. 你認為學生為什麼應該學生物學？
3. 你認為學生學生物的態度如何？
4. (1)你認為學生是以何種方式學生物學？(2)你認為那一種學習方式對學生的學習幫助最大？(3)你用什麼方式教生物？(4) 你認為那一種教學方式對學生的學習幫助最大？
5. 你在教生物學時，有什麼困難嗎？
6. 你認為學生藉著上生物課，確實學到了什麼？
7. 你對學生的學習成果和學業成就滿意嗎？
8. 學生學習生物學時，為什麼要作實驗？
9. 你是否認為，學生在日常生物理論課的學習，比實驗課有效率？
10. 你覺得學生作實驗的態度如何？他們很熱衷於作實驗嗎？
11. 你以教學生作實驗為樂嗎？
12. 如果你教生物理論時，沒有實驗課配合教學，你覺得如何？
13. 現有的生物理論課及實驗活動，有何優缺點？
14. 你希望現有的生物理論課及實驗課有什麼改變嗎？若是，如何改變？
15. 你對互動式教學及開放式活動有何看法？

Appendix 4

Student Interview 2 (SI 2)

1. How do you feel about the theory classes we currently have?
2. What are the differences between the current theory classes and the previous lecture classes?
3. What are the features of the current theory classes?
4. What have you learned the most from the current theory classes?
5. What have you learned from the teacher's questions?
6. What have you learned from peer discussion?
7. What are the strengths and weaknesses of the current theory classes?
8. Do you have any suggestions for improving the theory classes?
9. What responsibility do you think the teacher and student should take in teaching and learning?

學生晤談 2

1. 你對現在我們所上的生物理論課有何感受?
2. 我們現在所上的生物理論課，和你以前所上的有何不同?
3. 我們現在所上的生物理論課有何特點?
4. 你從現在我們所上的生物理論課中學到最多的是?
5. 你從老師的問題中學到什麼?
6. 你從同學的討論中學到什麼?
7. 現在所上的生物理論課有何優點和缺點?
8. 你有任何建議可以改善生物理論課嗎?
9. 你認為老師和學生在教學和學習上，應該各負什麼責任?

Appendix 5

Survey in Phase 1 (1)

Questionnaire 1 A (Student perceptions of the biology lecture classes in 1999)

1. Why are you taking biology? The main reason is (please rank the top three)
 - () able to increase entry options to university
 - () related to your future career
 - () having a strong interest in biology
 - () easy to learn
 - () able to help me understand myself and the surrounding environment
 - () the advice of the aptitude test
 - () the requirement of the department which I will choose in university
 - () affected by my families, relatives or celebrities
2. How much do you think your biology learning and satisfaction is (please circle the number)
 - a. Your interest toward biology Lots, Not much, Not sure, Little, Not at all
 - b. your biology knowledge: Lots, Not much, Not sure, Little, Not at all
 - c. your time spent on biology: Lots, Not much, Not sure, Little, Not at all
 - d. the influence of marks to motivation
 toward learning biology: Lots, Not much, Not sure, Little, Not at all
 - e. your self-satisfaction to biology
 learning: Lots, Not much, Not sure, Little, Not at all
 - f. your biology mark of previous semester is:
 100-81, 80-66, 65-51, 31-50, below 30.
3. Your difficulties in learning biology are: (You may tick more than one item):
 - a. In addition to learning basic biology theories, you have to learn another set of strategies to cope with tests;
 - b. Have no time and mood to grab non-test materials because you need to cope with the tests for other subjects;
 - c. You don't know how and where to get information;
 - d. You feel despair because low marks make you lose confidence;
 - e. Most tests are memory knowledge and you feel it is painful to recite them;

- f. The descriptions and the graphs in textbook are boring and not connected with real things;
 - g. Biology classes are not related to real life;
 - h. Some topics are too abstract to understand, such as genetics calculation or molecular biology;
 - i. You sometime cannot understand what the textbook is trying to express;
 - j. You don't know how to ask questions;
 - k. Some wrong or not clear conceptions prevent you from learning;
 - l. Learning biology well takes lots of time, so you can't cope with the tests of other subjects;
 - m. Others
4. (1) Which approaches do you prefer to use in learning biology?
 (2) Which approaches do you use in the present biology class?
 (3) Which approaches do you think most helpful in learning biology?
 (4) Which approaches do you think can increase your biology marks?

(You may tick more than one item for each question.)

	(1)	(2)	(3)	(4)
a. Carrying out school experiment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Peer discussion (in or out of class)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Participating in a teacher-led discussion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d. Visiting activity (museum, botany...)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
e. Attending biology relevant clubs or activities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
f. Field trips	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
g. Listening to a good lecture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
h. Reading the textbook	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
i. Copying summaries from the blackboard in class	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
j. Using test books and practising repeatedly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
k. Learning from press media	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
l. Reading books or magazines relevant to science	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
m. Watching videos or TV science programmes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
n. Teaching aids	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
o. Raising a pet or growing plants	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
p. Going out with families or friends (e.g. hiking)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
q. Country life observation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- r. Accessing the Internet
- s. Learning from the process of solving problems
- t. Others (1)_____ (2)_____ (3)_____ (4)_____

5. What will you do, if you encounter biological question in daily life?

- () Consult experts, teachers, classmates or friends,
 () Keep unanswered questions in mind,
 () Consult science books or magazines,
 () Give up,
 () Access the Internet,
 () Others.

6. (1) In what way does your biology teacher teach in the biology lecture class?
 (please circle one item)

Transmission Interaction Both Others_____

(2) How much are you satisfied with the present biology lecture classes?
 (please circle one item)

Lots Not much Not sure Little Not at all

7. Student expectations of a good teacher (please tick one item):

- () Clear interpretation and attractive teaching content;
 () Teaching in an interactive way, provide the students with opportunities to participate;
 () Writing down good lecture notes on the board for the students to copy;
 () Allowing the students have ownership while the teacher only provides assistance;
 () Others.

8. What are your opinions about the present biology lecture class? (Tick one item)

Weaknesses () monotonous teaching approach

- () feel embarrassed asking or being asked questions in class,
 () is unable to apply in daily life,
 () Others_____

Strengths () very efficient,

- () helpful to cope with test,
 () Others_____.

學生對生物理論課的感受 (1999 年)

1. 你選擇學生物，最主要是因為(請勾一項)

- a. 可以跨組，增加進大學的機會
- b. 與將來的職業有關
- c. 對生物有濃厚興趣
- d. 容易學
- e. 它很實用，可幫助我了解自己和環境
- f. 性向測驗的建議
- g. 我要唸的大學科系，要求要有生物成績
- h. 受家人、親朋好友、名人典範的影響

2. 你的生物學習與生物成績及自我滿意程度之關係為(請圈選一個數字)：

	非常	有些	沒意見	有點沒	完全沒有
a. 你對生物的興趣 (非常有→完全沒有)	5	4	3	2	1
b. 你的生物常識 (非常豐富→完全沒有)	5	4	3	2	1
c. 你花在生物的時間 (非常多→完全沒有)	5	4	3	2	1
d. 分數對學習生物的動機的影響(非常大→完全不會)	5	4	3	2	1
e. 對學習生物的自我滿意程度為(非常滿意→完全不滿意)	5	4	3	2	1
f. 你前一學期的生物成績是	100-81, 80-66, 65-51, 31-50, 30 以下				

3. 你學習生物的困難是(可勾多項)

- a. 除了學習基本的生物理論外，還要學另一套策略來應付考試
- b. 為了應付各科考試，沒時間也沒心情獲取生物的課外知識
- c. 不知那些途徑可得到生物資訊
- d. 你對生物絕望，因為低分讓你失去信心
- e. 考試內容多屬背誦，你覺得背起來很痛苦
- f. 課本敘述與圖片很無聊，無法與真實連貫起來
- g. 生物課和日常生活無關
- h. 有些生物的主題讓你覺得抽象難懂，例：遺傳計算或分子生物學..
- i. 你有時不太了解，教科書究竟要表達什麼
- j. 你不知如何發問
- k. 很多錯誤觀念或觀念不夠清楚，以至於妨礙學習
- l. 學好生物要花很多時間，如此一來，就不能應付其它科的考試了

- 4.請勾出右述四個問題的選項 (先作答(1)，然後(2)....
以免混淆) (可勾多項)
- | | (1) | (2) | (3) | (4) |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| 你喜歡用那些方式學習生物? | 你 | 你 | 什麼 | 什麼 |
| | 喜 | 現 | 方 | 方 |
| | 歡 | 在 | 式 | 式 |
| | 用 | 用 | 讓 | 較 |
| | 那 | 那 | 你 | 能 |
| | 些 | 些 | 覺 | 提 |
| | 方 | 方 | 得 | 昇 |
| | 式 | 式 | 最 | 生 |
| | 學 | 學 | 有 | 物 |
| | 習 | 習 | 幫 | 成 |
| | 生 | 生 | 助 | 績 |
| | 物 | 物 | ? | ? |
| | ? | ? | ? | ? |
| a.在學校實驗室作實驗 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| b.同學彼此討論 (課堂上或私下) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| c.參與老師主導的討論 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| d.參觀活動 (例：科博館、植物園....) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| e.參加與生物相關的活動或社團(例：賞鳥、生物研習社) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| f.野外 (實地) 調查 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| h.聽老師精彩的講課 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| i.讀教科書 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| j.在課堂上抄黑板的整理 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| k.寫參考書或測驗卷 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| l.從新聞媒體 (報紙、電視、廣播) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| m.讀科學書籍或雜誌 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| n.看科學節目 (錄影帶、第四台....) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| o.實物模型或圖片...等教具 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| p.飼養動物或種植花草的經驗 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| q.隨家人或親朋好友出遊 (登山、遠足) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| r.鄉居生活的觀察 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| s.利用網路查詢 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| t.從解決問題的過程中學習 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| u.其它 (1)_____ (2)_____ (3)_____ (4)_____ | | | | |
- 5.對於日常生活產生的生物疑問，你通常會(請勾最主要的一項)
- ()請教專家、老師、同學、親友
- ()存疑在心中，日後有機會再解決
- ()查書(百科全書、科學雜誌、報紙.....)

- 放棄
 - 利用網路查詢
 - 其它_____
- 6.(1)你的生物老師上課方式是(請勾一項)
- 傳授式(老師說,學生聽)
 - 互動式(師生互問互答)
 - 傳授式兼互動式
 - 其它_____
- (2)你對現在生物正課的上課方式
- 非常滿意
 - 有點滿意
 - 沒意見
 - 有點不滿意
 - 非常不滿意
- 7.你認為很好的生物老師就是(請勾一項)
- 清楚的解釋及吸引學生的講課內容
 - 上課以互動方式,讓學生有參與的機會
 - 把筆記整理得很好,讓學生抄
 - 讓學生自己作、自己想,老師只是提供協助
 - 其它_____
- 8.你認為現有生物理論課的(可勾多項)
- (1)缺點是
- 上課方式很單調
 - 上課不敢問問題,也不敢回答
 - 不能應用到日常生活
 - 其它_____
- (2)優點是
- 很有效率
 - 對考試很有幫助
 - 其它_____

Appendix 6

Survey in Phase 1 (2)

Questionnaire 1B (student perceptions of the biology experiment classes in 1999)

Please indicate the degree of agreement. (Only circle one number)

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

1. I like doing experiments. 5 4 3 2 1
 2. From watching teacher's well-organised demonstration students
learn more experiments by themselves than doing one. 5 4 3 2 1
 3. I can't understand biology concepts without doing
experiments. 5 4 3 2 1
 4. By doing experiments I obtain knowledge rather than life
applications. 5 4 3 2 1
 5. The discussion is more important than the result of
experiment. 5 4 3 2 1
 6. I am satisfied with the present biology experiment class. 5 4 3 2 1
 7. (1) What do you think you could learn or obtain from the biology experiment
class?
 - (2) What do you think you actually learn or obtain from the present biology
experiment classes? (Please tick one item for each sub-question)
- | | | |
|--|-----|-----|
| | (1) | (2) |
|--|-----|-----|
- a. To enable abstract biological concepts more real.
 - b. To obtain more concept.
 - c. To enhance the ability of thinking and analysing.
 - d. To increase creativity.
 - e. To verify theories.
 - f. To learn from errors or failures.
 - g. To make new discoveries.
 - h. For a lasting effect to cope with tests.
 - i. To familiarize oneself with the procedure of solving problems

- such as observing, making hypothesis.....
- j. To manipulate equipment.
- k. To give an opportunity for experiencing science.
- l. To cooperate and negotiate.
- m. To judge from class discussion.
- n. To promote interest.
- o. To satisfy curiosity.
- p. To have a sense of achievement.
- q. To become more patient, attentive and responsible.
- r. To increase friendship.
- s. Others (1)_____ (2)_____

8. Before doing experiments, teacher's instruction and demonstration.

(Please tick one item)

- () are unnecessary,
- () are helpful to avoid too many variables generated,
- () could prevent from making mistakes,
- () could avoid ignoring some important steps,
- () others_____.

9. Please indicate the frequency of the following situation. (Please circle one number)

Always	Often	Sometimes	Seldom	Never
5	4	3	2	1

- (1) I am the performer of each experiment. 5 4 3 2 1
 - (2) I can't concentrate on doing experiments due to chatting with others. 5 4 3 2 1
10. At the end of the present biology experiment class: (please tick one item)
- () we don't have any discussion, just dismissed;
 - () each group shows its data to the class without any explanation.
 - () teacher compares the data and gives explanations;
 - () every group shows the data to the class and gives explanations, then the discussion starts with teacher's assistance;
 - Others_____.

11. (1) Which type of activity do you like in the biology experiment class?

- (2) Which type of activity do you engage the present biology experiment class? (please tick one item for each sub-question) (1) (2)
- a. Problem area, equipment, methods of solution, and correct results are given or obvious by the lab manual;
- b. Problems, equipment, methods of solution are provided;
- c. Problems are posed, but methods and answers are left open;
- d. Problems, methods, and answers are left open.

12. My experiments are not significant as scientists, hence, it is unnecessary for me to make an hypothesis before doing experiments. Do you agree with the above statement?

Always	Often	Sometimes	Seldom	Never
5	4	3	2	1

13. What are your opinions about the present biology experiment classes?

(You can tick more than one item)

- Weaknesses () Too many students in a group to do experiments,
 () Unrelated to daily life,
 () Little autonomy,
 () Time constraint,
 () Little discussion at the end of an experiment class,
 () Often being interrupted by classmates,
 () Old and broken apparatus,
 () Experiments following instruction providing little opportunities to stimulate thinking,
 () Few experiments,
 () Assessments need to be improved,
 () The experiments are too simple to enhance creativity,
 () Others_____.
- Strengths () Helpful to cope with tests,
 () To avoid making mistakes,
 () Sufficient equipment to use,
 () Others_____.

學生對生物實驗課的感受 (1999 年)

		非 常 同 意	有 點 同 意	沒 有 見 解	有 點 不 同 意	非 常 不 同 意
(請圈選一個數字)						
1.我喜歡作生物實驗	5	4	3	2	1	
2.我覺得學生從老師示範實驗中學，比學生自己作實驗 還要學得多，因為前者有完善的規劃和組織性	5	4	3	2	1	
3.如果不作實驗，就無法了解生物觀念	5	4	3	2	1	
4.藉著作實驗，我獲得知識而非生活應用	5	4	3	2	1	
5.我覺得討論比生物實驗的結果來得重要	5	4	3	2	1	
6.我對現有生物實驗課很滿意	5	4	3	2	1	
7.請勾出右述兩個問題的選項，先作答(1)，然後(2)						
，以免混淆 (可勾多項)		(1)		(2)		
		我	其	覺	實	
				得	作	
				作	實	
				實	驗	
				驗	可	
				可	以	
				以	以	
a.使抽象的生物概念變得更具體		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
b.獲得更多觀念		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
c.加強思考、分析能力		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
d.增加創造力	<input type="checkbox"/>		<input type="checkbox"/>			
e.證明理論	<input type="checkbox"/>		<input type="checkbox"/>			
f.從錯誤或失敗中學	<input type="checkbox"/>		<input type="checkbox"/>			
g.有新發現	<input type="checkbox"/>		<input type="checkbox"/>			
h.加深印象，有助於應付考試	<input type="checkbox"/>		<input type="checkbox"/>			
i.熟悉解決問題的步驟，例如:觀察→建立假說....				<input type="checkbox"/>	<input type="checkbox"/>	
j.熟悉操作儀器				<input type="checkbox"/>	<input type="checkbox"/>	
k.提供機會體驗科學	<input type="checkbox"/>		<input type="checkbox"/>			

- | | | |
|------------------------|--------------------------|--------------------------|
| l.學習合作和協商 | <input type="checkbox"/> | <input type="checkbox"/> |
| m.從班級討論中作出判斷 | <input type="checkbox"/> | <input type="checkbox"/> |
| n.加強興趣 | <input type="checkbox"/> | <input type="checkbox"/> |
| o.滿足好奇心 | <input type="checkbox"/> | <input type="checkbox"/> |
| p.讓人覺得有成就感 | <input type="checkbox"/> | <input type="checkbox"/> |
| q.學習更有耐性、細心和負責 | <input type="checkbox"/> | <input type="checkbox"/> |
| r.增進同學情誼 | <input type="checkbox"/> | <input type="checkbox"/> |
| s.其它(1) _____(2) _____ | | |

8.作生物實驗以前，老師的講解與示範，我認為(請勾一項)

- () a.不需要
 () b.可幫助避免過多變因的產生
 () c.可避免犯錯
 () d.可避免忽略某些重要步驟
 () e.其它 _____

9.在實驗分組中(請圈選一個數字)，

	常	有	很	偶	從
	常	時	少	而	未
(1)我擔任實驗操作者的機會是	5	4	3	2	1
(2)我常和同學閒聊而不能專心作實驗的機會是	5	4	3	2	1

10.在現有的生物實驗課結束時(請勾一項)

- () a.我們作完實驗就下課，沒有討論
 () b.各組把數據抄在黑板或報告出來，但沒有解釋原因
 () c.老師比較全班數據並作解釋
 () d.各組對自己的數據提出解釋，在老師的協助下，全班進行討論
 () e.其它 _____

11.關於生物實驗課的進行方式(從封閉到開放)，請勾一項：

- | | | |
|---------------------------------------|--------------------------|--------------------------|
| | 你 | 現 |
| (1)在現有的生物實驗課，你喜歡哪種活動方式? | 喜 | 參 |
| (2)在現有的生物實驗課，你參與的是哪種活動方式? | 歡 | 與 |
| a.實驗課本提供實驗題目、器材和設備、方法、正確的結果，
老師先示範 | <input type="checkbox"/> | <input type="checkbox"/> |
| b.實驗課本提供實驗題目、器材和設備、方法，讓學生自己
發現結果 | <input type="checkbox"/> | <input type="checkbox"/> |
| c.實驗課本只提供實驗題目，其餘讓學生自己去設計與發現 | <input type="checkbox"/> | <input type="checkbox"/> |
| d.學生自定題目，自己設計與完成實驗 | <input type="checkbox"/> | <input type="checkbox"/> |

12. 我的實驗不像科學家作的實驗那麼重要，因此作實驗前不需要建立假說，你同意這個說法嗎？

- 非常同意 有點同意 沒意見 有點不同意
 非常不同意

13. 你認為現有生物實驗課的(可勾多項)

(1)缺點是

- a. 小組人數太多
 b. 不能應用到日常生活
 c. 沒有自主性
 d. 時間受限制
 e. 實驗結束前沒有討論
 f. 作實驗常常會被同學打斷
 g. 儀器老舊、破損
 h. 只照著課本作實驗，少有機會訓練思考能力
 i. 實驗次數太少
 j. 評量方式有待改進
 k. 實驗太簡單，沒有機會培養創造力
 l. 其它 _____

(2)優點是

- a. 幫助應付考試
 b. 比較不會犯錯
 c. 儀器很夠用
 d. 其它 _____

Appendix 7

Tsai's Pomeroy Questionnaire

Please respond to the statements below using the corresponding number.

Agree	Slightly agree	Neutral	Slightly disagree	Disagree
5	4	3	2	1

After each statement, please answer the following: 'Concerning this choice, I am: (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.' honestly. These questions have no specific answers; please consider them in detail, and then reply. Thank you!

- 5 4 3 2 1 **1.** The process of scientific discovery often involves an ability to look at things in ways which are not commonly accepted.
 () To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **2.** Intuition plays an important role in scientific discovery.
 () To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **3.** Science is the ideal of knowledge in that it is a set of statements which are objective; i.e. their substance is determined entirely from observation.
 () To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **4.** Scientists rigorously attempt to eliminate human perspective from our picture of the world.
 () To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **5.** Insofar as a theory cannot be tested by experience, it ought to be revised so that its predictions are restricted to observable phenomenon.
 () To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.

- 5 4 3 2 1 **6.** Different cultural groups have different processes of gaining valid knowledge of natural laws.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **7.** Legitimate scientific ideas sometimes come from dreams and hunches.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **8.** Because of the validity of scientific method, knowledge obtained by its application is determined more by nature itself than by the choices the scientists make.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **9.** Science is a set of practices and a body of knowledge developed by a specific community of people.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **10.** The process of scientific discovery often involves purposeful discard of accepted theory.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **11.** The purpose of science is to establish intellectual control over experience in term of precise laws which can be formally set out and empirically tested.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **12.** There is a significant amount of scientific knowledge in folklore and myth.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **13.** It is not unusual for scientists to get ideas from a variety of seemingly unrelated scientific and non-scientific sources.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.

- 5 4 3 2 1 **14.** The best way to prepare to become a scientist is to master the scientific body of knowledge available in the finest texts.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **15.** Non-sequential thinking, i.e. taking conceptual leaps, is characteristic of many scientists.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **16.** Scientists integrate many processes concurrently.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **17.** Most scientists believe nature strictly obeys laws.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **18.** Scientific knowledge starts with observations of nature.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **19.** The acquisition of new scientific knowledge moves from observation to hypothesis to testing to generalizing to theory.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.
- 5 4 3 2 1 **20.** There are some scientific studies which are considered valid and significant which are not based on experimentation.
() To my choice, I am (1) guessing, (2) uncertain, (3) fairly certain, (4) sure.

Tsai's Pomeroy 中文問卷

請用下列的指標（1，2，3，4，5）來代表你對以下所有陳述的意見，請你用圓圈將你所認為適當的答案圈選出來

5 = 幾乎完全同意

4 = 大致而言同意

3 = 同意與不同意的程度幾乎相同

2 = 大致而言不同意

1 = 幾乎完全不同意

請在每個陳述前之號碼中圈選出你的意見，例如 5 4 3 2 1，代表你大致同意這項敘述。如果你想更改答案，你可以直接劃掉原有的答案並圈選一個新答案，例如 5 4 3 2 1。在每個陳述後，對於你所選的指標反應，請誠實回答你是用（1）用猜的（2）不太確定（3）蠻確定的（4）非常確定，對於後面這個問題，請將你的答案填在此問題前的括弧內，例如（3）代表你對於你所選的指標是蠻確定的。請注意，這些問題是沒有特定答案的，但請仔細思考後再做答，謝謝！

-
- 5 4 3 2 1 1. 在科學知識形成的過程中經常包含了一種不是平常被接受的看待事情的能力。
() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 2. 直覺在科學發現的過程中扮演一個重要的角色。
() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 3. 科學是一種知識的模範，因為它是客觀的陳述，也就是說，它的內容完全取決於現象的觀察。
() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 4. 科學家很努力的想從我們看待世界的眼光中消除人的觀點。
() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 5. 當經驗不能測試一個科學理論時，科學家一定要修改這個理論，直到它可以被觀察得到現象測試為止。

- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **6.** 不同文化族群的人(例如：中國人，非洲人，歐洲人)有不同的方法或過程來獲得有效的科學知識。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **7.** 一些被接受的科學知識有時是從人類幻想與預感而來的。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **8.** 因為有特定獲得科學知識的方法，所以科學知識主要是從大自然本身而來的，而不是從科學家的自主性的選擇與介入而來的。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **9.** 科學是由屬於一個特定社群的人，發展出的一系列的慣例、演算和一堆知識。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **10.** 科學發現的過程中，常刻意放棄一些被接受的理論。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **11.** 科學的目的，是用我們已證明的正確定律來控制自然經驗。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **12.** 有一部份的科學知識來自民間傳說與神話。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **13.** 科學家有時從一些看起來不是很相關的知識或理論中(不論是科學的或不科學的)，得到解決問題的靈感與想法。
- () 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。
- 5 4 3 2 1 **14.** 培育一個科學家的最好方法是讓他熟悉明瞭在最好的教

科書裡的那一堆知識。

() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。

5 4 3 2 1 **15.** 非連續性的思考，也就是說，觀念上的突然的重大改變，是許多科學家的特性。

() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。

5 4 3 2 1 **16.** 在科學知識形成的過程中，科學家可同時整合好幾種步驟。

() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。

5 4 3 2 1 **17.** 大部分的科學家認為大自然很嚴謹地遵照一定的法則或定律在運作。

() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。

5 4 3 2 1 **18.** 科學知識是始於大自然的觀察。

() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。

5 4 3 2 1 **19.** 新科學知識的獲得，是從觀察→假說→實驗→學說而來。

() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。

5 4 3 2 1 **20.** 有些科學研究被視為很有價值也很重要，但此一認定並非根據實驗結果。

() 對於我的這個選擇反應，我是(1)用猜的(2)不太確定(3)蠻確定的(4)非常確定。

Appendix 8

Confidence Questionnaire

	Very confident	Reasonable confident	Not very confident	Not confident at all
I can make hypotheses (predictions).				
I can do an investigation where there is more than one changing factor.				
I can make decisions about how many animals or plants to use when I am doing an investigation.				
I can make decisions about how many times to repeat an experiment.				
I can select appropriate equipment to carry out an experiment.				
I can take measurements using appropriate measuring devices.				
I can identify the sources of error in my experimental method.				
I can present data in an appropriate form.				
I can analyse data.				
I can make conclusions.				
I can justify my conclusions.				
I can use appropriate language and layout when presenting what I have found out.				
I can re-design experiments when my first results are unconvincing.				
I can say when it is appropriate to apply what I have found out to other situations.				

實驗自信問卷調查

各位同學：

在你設計、進行與報告實驗之前，你知道你有多少自信，來作這些工作嗎？

請依照你覺得你有多少自信，在每個敘述的空格裏，勾選你的感受。

	非常有 自信	有點有 自信	不很有 自信	完全沒 自信
我能建立假說(預測)				
我能作「不只改變一個因子」 的實驗				
當我在作實驗時，我能決定我 要用哪些動植物				
在重複作實驗時，我能決定我 要作多少次				
我能選擇適當的器材作實驗				
我能用適當的設備儀器作測量				
在我用的實驗方法中，我能確 定實驗誤差來自何處				
我能用適當的形式表達我的實 驗數據				
我能分析實驗數據				
我能作出結論				
我能證明我的結論				
當要報告我所發現的結果時， 我能用適當的語言、書面說明 來呈現它				
當我的原始數據無法令人信服 時，我能重新設計該實驗				
我能說明我的實驗結果很適合 應用到哪些情況				

Appendix 9

Survey in Phase 3 (1)

Appendix 9.1: Questionnaire 2A1 (The traditional student perceptions of the biology lecture classes in 2001)

Please respond to the statements below using the corresponding number.

Agree	Slightly agree	Neutral	Slightly disagree	Disagree
5	4	3	2	1

Teacher

- | | | | | | |
|---|---|---|---|---|---|
| 1. Making the students understand teaching content is the teacher's responsibility. | 5 | 4 | 3 | 2 | 1 |
| 2. I wish my teacher could supply more knowledge. | 5 | 4 | 3 | 2 | 1 |

Teaching

- | | | | | | |
|---|---|---|---|---|---|
| 1. The current teaching way is very effective to help us acquire lots of knowledge in a short time. | 5 | 4 | 3 | 2 | 1 |
| 2. The teacher spent much time in student discussion. | 5 | 4 | 3 | 2 | 1 |
| 3. The teaching approach could stimulate my interest in learning biology. | 5 | 4 | 3 | 2 | 1 |
| 4. The teaching content is related to my daily life. | 5 | 4 | 3 | 2 | 1 |
| 5. The teaching approach is monotonous. | 5 | 4 | 3 | 2 | 1 |
| 6. The teaching content is not abstract for me. | 5 | 4 | 3 | 2 | 1 |
| 7. From group and whole discussion, my concepts were clarified more clearly. | 5 | 4 | 3 | 2 | 1 |

Learning

- | | | | | | |
|---|---|---|---|---|---|
| 1. I spend much time in thinking and negotiating with my classmates in the current lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 2. I spend much time copying notes in the current lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 3. The main responsibility of the student is studying well and | | | | | |

earning marks.	5	4	3	2	1
4. Whether I can have better learning depends on the teacher.	5	4	3	2	1
5. I have little doubt about the teacher's lectures.	5	4	3	2	1
6. I know how to get better learning from the biology classes.	5	4	3	2	1
7. I can apply what I have learned in the current lecture classes to my daily life.	5	4	3	2	1
8. I would like to seek more information about what we have discussed.	5	4	3	2	1
9. Clear notes would be better than learning from discussion.	5	4	3	2	1

Overall appraisal

1. I am not sure I can cope with tests by the current lecture classes.	5	4	3	2	1
2. I like the current biology classes	5	4	3	2	1
3. The time passed quickly in biology classes.	5	4	3	2	1
4. The current lecture classes are helpful to my learning in biology.	5	4	3	2	1
5. I am very satisfied with the current biology classes.	5	4	3	2	1

學生對傳統生物理論課的感受 (2001年)

開學至今，生物課給你（妳）何種感受？請根據你同意的程度圈選出相對應的數字：同意：5 有點同意：4 沒意見：3 有點不同意：2 不同意：1

老師

- | | | | | | |
|-------------------------|---|---|---|---|---|
| 1.老師的責任是要使學生了解他(她)的授課內容 | 5 | 4 | 3 | 2 | 1 |
| 2.我希望我的老師能提供更多的知識 | 5 | 4 | 3 | 2 | 1 |

教學

- | | | | | | |
|-------------------------------|---|---|---|---|---|
| 1.現有的教學方式很有效率，幫助我們在短時間內獲得很多知識 | 5 | 4 | 3 | 2 | 1 |
| 2.老師花很多時間在學生的討論上 | 5 | 4 | 3 | 2 | 1 |
| 3.老師的教學方式能引起我對學習生物的興趣 | 5 | 4 | 3 | 2 | 1 |
| 4.老師上課教的內容與日常生活有關 | 5 | 4 | 3 | 2 | 1 |
| 5.生物課的上課方式很單調 | 5 | 4 | 3 | 2 | 1 |
| 6.老師上課教的內容，對我而言並不抽象 | 5 | 4 | 3 | 2 | 1 |
| 7.藉著分組和全班討論，我的觀念更被釐清 | 5 | 4 | 3 | 2 | 1 |

學習

- | | | | | | |
|-----------------------------|---|---|---|---|---|
| 1.在現有的生物課中，我花較多的時間在思考及與同學協商 | 5 | 4 | 3 | 2 | 1 |
| 2.我花很多時間在課堂上抄筆記 | 5 | 4 | 3 | 2 | 1 |
| 3.學生最主要的責任，是把書唸好、成績考好 | 5 | 4 | 3 | 2 | 1 |
| 4.我能否有好的學習視老師而定 | 5 | 4 | 3 | 2 | 1 |
| 5.我對老師上課教的內容，幾乎沒什麼疑問 | 5 | 4 | 3 | 2 | 1 |
| 6.我知道怎麼樣能在生物課學得更好 | 5 | 4 | 3 | 2 | 1 |
| 7.我能將生物課所學的東西應用到日常生活中 | 5 | 4 | 3 | 2 | 1 |
| 8.對於我們在課堂上討論的東西，我願意去找更多資料 | 5 | 4 | 3 | 2 | 1 |
| 9.清楚的筆記勝於從討論中所學的東西 | 5 | 4 | 3 | 2 | 1 |

整體評量

1.現有的生物課，讓我沒把握應付考試	5	4	3	2	1
2.我很喜歡現有的生物課	5	4	3	2	1
3.上生物課時，時間過得好快	5	4	3	2	1
4.現有的生物課對我學習生物很有幫助	5	4	3	2	1
5.我對現有的生物課的滿意程度是	5	4	3	2	1

Appendix 9.2: Questionnaire 2A2 (The intervention student perceptions of biology interactive teaching classes in 2001)

Please respond to the statements below using the corresponding number.

Agree	Slightly agree	Neutral	Slightly disagree	Disagree
5	4	3	2	1

Teacher

1. Making the students understand his/her teaching content is the teacher's responsibility. 5 4 3 2 1
2. I wish my teacher could supply more knowledge. 5 4 3 2 1

Teaching

1. The current teaching way is very effective to help us acquire lots of knowledge in a short time. 5 4 3 2 1
2. The teacher spent much time in student discussion. 5 4 3 2 1
3. The teaching approach could stimulate my interesting in learning biology. 5 4 3 2 1
4. The student prior knowledge is very important to the interactive teaching. 5 4 3 2 1
5. The teaching content is related to my daily life. 5 4 3 2 1
6. The teaching approach is monotonous. 5 4 3 2 1
7. The teaching content is not abstract for me. 5 4 3 2 1
8. From group and whole discussion, my concepts were clarified more clearly. 5 4 3 2 1
9. The current lecture class is relaxed and without any pressure. 5 4 3 2 1
10. Interactive teaching is very boring. I do not know what I should do during class time. 5 4 3 2 1

Learning

1. I spent more time in thinking and negotiating with my classmates in the current lecture classes. 5 4 3 2 1

- | | | | | | |
|---|---|---|---|---|---|
| 2. I spent much time in copying notes in the current lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 3. The main responsibility of the student is studying well and earning marks. | 5 | 4 | 3 | 2 | 1 |
| 4. Whether I can learn better learning depends on the teacher. | 5 | 4 | 3 | 2 | 1 |
| 5. I have little doubt about the teacher's lectures. | 5 | 4 | 3 | 2 | 1 |
| 6. I know how to learn better from the biology class. | 5 | 4 | 3 | 2 | 1 |
| 7. I can apply what I have learned in the current lecture classes to my daily life. | 5 | 4 | 3 | 2 | 1 |
| 8. I would like to seek more information about what we have discussed. | 5 | 4 | 3 | 2 | 1 |
| 9. Clear notes would be better than learning from discussion. | 5 | 4 | 3 | 2 | 1 |

Overall appraisal

- | | | | | | |
|---|---|---|---|---|---|
| 1. I am not sure I can cope with tests after the current lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 2. I like the current biology classes. | 5 | 4 | 3 | 2 | 1 |
| 3. The time passed quickly in biology classes. | 5 | 4 | 3 | 2 | 1 |
| 4. It is worth spending time in interactive teaching. | 5 | 4 | 3 | 2 | 1 |
| 5. Interactive teaching increases my confidence. | 5 | 4 | 3 | 2 | 1 |
| 6. The current lecture classes are helpful to my learning in biology. | 5 | 4 | 3 | 2 | 1 |
| 7. I am very satisfied with the current biology classes. | 5 | 4 | 3 | 2 | 1 |
| 8. Is interactive teaching feasible? Why? | | | | | |

學生對互動式生物理論課的感受 (2001 年)

開學至今，生物課給你（妳）何種感受？請根據你同意的程度圈選出相對應的數字：同意：5 有點同意：4 沒意見：3 有點不同意：2 不同意：1

老師

- | | | | | | |
|-------------------------|---|---|---|---|---|
| 1.老師的責任是要使學生了解他(她)的授課內容 | 5 | 4 | 3 | 2 | 1 |
| 2.我希望我的老師能提供更多的知識 | 5 | 4 | 3 | 2 | 1 |

教學

- | | | | | | |
|-------------------------------|---|---|---|---|---|
| 1.現有的教學方式很有效率，幫助我們在短時間內獲得很多知識 | 5 | 4 | 3 | 2 | 1 |
| 2.老師花很多時間在學生的討論上 | 5 | 4 | 3 | 2 | 1 |
| 3.老師的教學方式能引起我對學習生物的興趣 | 5 | 4 | 3 | 2 | 1 |
| 4.學生現有的已知知識，對互動式教學而言很重要 | 5 | 4 | 3 | 2 | 1 |
| 5.老師上課教的內容與日常生活有關 | 5 | 4 | 3 | 2 | 1 |
| 6.生物課的上課方式很單調 | 5 | 4 | 3 | 2 | 1 |
| 7.老師上課教的內容，對我而言並不抽象 | 5 | 4 | 3 | 2 | 1 |
| 8.藉著分組和全班討論，我的觀念更被釐清 | 5 | 4 | 3 | 2 | 1 |
| 9.互動式教學上課很輕鬆，沒有壓力 | 5 | 4 | 3 | 2 | 1 |
| 10.互動式教學很無聊，上課常不知道要作什麼 | 5 | 4 | 3 | 2 | 1 |

學習

- | | | | | | |
|-----------------------------|---|---|---|---|---|
| 1.在現有的生物課中，我花較多的時間在思考及與同學協商 | 5 | 4 | 3 | 2 | 1 |
| 2.我花很多時間在課堂上抄筆記 | 5 | 4 | 3 | 2 | 1 |
| 3.學生最主要的責任，是把書唸好、成績考好 | 5 | 4 | 3 | 2 | 1 |
| 4.我能否有好的學習視老師而定 | 5 | 4 | 3 | 2 | 1 |
| 5.我對老師上課教的內容，幾乎沒什麼疑問 | 5 | 4 | 3 | 2 | 1 |
| 6.我知道怎麼樣能在生物課學得更好 | 5 | 4 | 3 | 2 | 1 |
| 7.我能將生物課所學的東西應用到日常生活中 | 5 | 4 | 3 | 2 | 1 |

- | | | | | | |
|---------------------------|---|---|---|---|---|
| 8.對於我們在課堂上討論的東西，我願意去找更多資料 | 5 | 4 | 3 | 2 | 1 |
| 9.清楚的筆記勝於從討論中所學的東西 | 5 | 4 | 3 | 2 | 1 |

整體評量

- | | | | | | |
|---|---|---|---|---|---|
| 1.現有的生物課，讓我沒把握應付考試 | 5 | 4 | 3 | 2 | 1 |
| 2.我很喜歡現有的生物課 | 5 | 4 | 3 | 2 | 1 |
| 3.上生物課時，時間過得好快 | 5 | 4 | 3 | 2 | 1 |
| 4..互動式教學很值得花時間 | 5 | 4 | 3 | 2 | 1 |
| 5.互動式教學增加我的自信 | 5 | 4 | 3 | 2 | 1 |
| 6.現有的生物課，對我學習生物很有幫助 | 5 | 4 | 3 | 2 | 1 |
| 7.我對互動式教學的滿意程度是(不要考慮高三是否可行，
只要提出你個人的滿意度) | 5 | 4 | 3 | 2 | 1 |
| 8.討論式的上課方法可行嗎？為什麼？ | | | | | |

Appendix 10

Survey in Phase 3 (2)

Appendix 10.1: Questionnaire 2B1 (The traditional student perceptions of the biology experiment classes in 2001)

Please respond to the statements below using the corresponding number.

Agree	Slightly agree	Neutral	Slightly disagree	Disagree
5	4	3	2	1

- | | | | | | |
|---|---|---|---|---|---|
| 1. I feel these investigations are interesting. | 5 | 4 | 3 | 2 | 1 |
| 2. I follow the instructions to do the investigations. | 5 | 4 | 3 | 2 | 1 |
| 3. I am depressed about my experimental results. | 5 | 4 | 3 | 2 | 1 |
| 4. My teacher didn't provide me with sufficient cues in doing investigations. | 5 | 4 | 3 | 2 | 1 |
| 5. I learned only manipulation skills from the investigations. | 5 | 4 | 3 | 2 | 1 |
| 6. Some concepts were learned from these investigations. | 5 | 4 | 3 | 2 | 1 |
| 7. These investigations were very difficult for me. | 5 | 4 | 3 | 2 | 1 |
| 8. These investigations were less efficient than the lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 9. These investigations could be replaced by the lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 10. These investigations are time consuming. | 5 | 4 | 3 | 2 | 1 |
| 11. These investigations are worthwhile. | 5 | 4 | 3 | 2 | 1 |
| 12. These investigations were related to my daily life. | 5 | 4 | 3 | 2 | 1 |
| 13. I have to apply what I have learned in order to undertake the investigations. | 5 | 4 | 3 | 2 | 1 |
| 14. I will transfer the skills I learned from the investigations to my daily life. | 5 | 4 | 3 | 2 | 1 |
| 15. I need to discuss and negotiate with my group members to accomplish the investigations. | 5 | 4 | 3 | 2 | 1 |
| 16. These investigations enhanced my ability to design an investigation. | 5 | 4 | 3 | 2 | 1 |

17. These investigations enhanced my abilities to interpret data.	5	4	3	2	1
18. These investigations encouraged my creativity and initiative.	5	4	3	2	1
19. These investigations enhanced my learning in biology knowledge.	5	4	3	2	1
20. The investigations increased my confidence in doing investigations.	5	4	3	2	1
21. The investigations assisted me to understand how scientists work.	5	4	3	2	1
22. The investigations stimulated my thinking.	5	4	3	2	1
23. The investigations are challenging tasks for me.	5	4	3	2	1
24. I am satisfied with the current experiment classes.	5	4	3	2	1

學生對傳統生物實驗課的感受 (2001 年)

開學至今，生物實驗課給你（妳）何種感受？請根據你同意的程度圈選出相對應的數字：

同意：5 有點同意：4 沒意見：3 有點不同意：2 不同意：1

1.我覺得現有的實驗課很有趣	5	4	3	2	1
2.我照著老師給我的方法和步驟作實驗	5	4	3	2	1
3.對於我的實驗結果，我覺得有點沮喪	5	4	3	2	1
4.在作實驗時，老師沒有提供足夠的線索給我	5	4	3	2	1
5.從這些實驗中，我只學到實驗操作的技巧	5	4	3	2	1
6.我從這些實驗中，學到了一些觀念	5	4	3	2	1
7.這些實驗對我而言很困難	5	4	3	2	1
8.這些實驗比上正課來得沒效率	5	4	3	2	1
9.這些實驗可以用理論課來取代	5	4	3	2	1
10.這些實驗很浪費時間	5	4	3	2	1
11.這些實驗很值得去作	5	4	3	2	1
12.這些實驗與我的日常生活有關	5	4	3	2	1
13.我作這些實驗必須應用到從前學到的東西	5	4	3	2	1
14.我會把我從這些實驗中所學到的技巧，運用到我的 日常生活中	5	4	3	2	1
15.我需要和組內成員討論與協商，以完成這些實驗	5	4	3	2	1
16.這些實驗加強我設計實驗的能力	5	4	3	2	1
17.這些實驗加強我解釋實驗的能力	5	4	3	2	1
18.這些實驗促進我的創造力和主動性	5	4	3	2	1
19.這些實驗加強我學習生物知識	5	4	3	2	1
20.這些實驗增加我作實驗的自信	5	4	3	2	1
21.這些實驗促使我了解什麼科學家如何作研究	5	4	3	2	1
22.這些實驗刺激我的思考	5	4	3	2	1
23.這些實驗對我而言，具有挑戰性	5	4	3	2	1
24.我對現有實驗的滿意程度是	5	4	3	2	1

Appendix 10.2: Questionnaire 2B2 (The intervention student perceptions of the biology open investigations in 2001)

Please respond to the statements below using the corresponding number.

Agree	Slightly agree	Neutral	Slightly disagree	Disagree
5	4	3	2	1

- | | | | | | |
|---|---|---|---|---|---|
| 1. I feel the investigations are interesting. | 5 | 4 | 3 | 2 | 1 |
| 2. I quite enjoyed making decisions by myself. | 5 | 4 | 3 | 2 | 1 |
| 3. I am depressed about my experimental results. | 5 | 4 | 3 | 2 | 1 |
| 4. My teacher didn't provide sufficient cues in doing investigations. | 5 | 4 | 3 | 2 | 1 |
| 5. The teacher explained the investigations vaguely, hence I was not sure how to do investigations. | 5 | 4 | 3 | 2 | 1 |
| 6. The investigations were very difficult for me. | 5 | 4 | 3 | 2 | 1 |
| 7. The investigations were less efficient than the lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 8. I learned only manipulation skills from the investigation. | 5 | 4 | 3 | 2 | 1 |
| 9. Some concepts were learned from these investigations. | 5 | 4 | 3 | 2 | 1 |
| 10. The investigations could be replaced by the lecture classes. | 5 | 4 | 3 | 2 | 1 |
| 11. The investigations are time consuming. | 5 | 4 | 3 | 2 | 1 |
| 12. The investigations were worthwhile. | 5 | 4 | 3 | 2 | 1 |
| 13. The investigations related to my daily life. | 5 | 4 | 3 | 2 | 1 |
| 14. I have to apply what I have learned in order to undertake the investigations. | 5 | 4 | 3 | 2 | 1 |
| 15. I will transfer the skills I learned from the investigations to my daily life. | 5 | 4 | 3 | 2 | 1 |
| 16. I need to discuss and negotiate with my group members to accomplish the investigations. | 5 | 4 | 3 | 2 | 1 |
| 17. The investigations enhanced my ability to design an investigation. | 5 | 4 | 3 | 2 | 1 |
| 18. These investigations enhanced my abilities to interpret data. | 5 | 4 | 3 | 2 | 1 |

- | | | | | | |
|---|---|---|---|---|---|
| 19. The investigations encouraged my creativity and initiative. | 5 | 4 | 3 | 2 | 1 |
| 20. These investigations enhanced my learning in biology knowledge. | 5 | 4 | 3 | 2 | 1 |
| 21. The investigations increased my confidence in doing investigations. | 5 | 4 | 3 | 2 | 1 |
| 22. The investigations assisted me to understand how scientists work. | 5 | 4 | 3 | 2 | 1 |
| 23. The investigations stimulated my thinking. | 5 | 4 | 3 | 2 | 1 |
| 24. The investigations are challenging tasks for me. | 5 | 4 | 3 | 2 | 1 |
| 25. I am satisfied with the current experiment classes. | 5 | 4 | 3 | 2 | 1 |
| 26. Are open investigations feasible? Give reasons. | | | | | |

學生對開放式生物實驗的感受 (2001 年)

開學至今，生物實驗課給你（妳）何種感受？請根據你同意的程度圈選出相對應的數字：

同意：5 有點同意：4 沒意見：3 有點不同意：2 不同意：1

1.我覺得現有的實驗課很有趣	5	4	3	2	1
2.我很享受「自己作決定」的樂趣	5	4	3	2	1
3.對於我的實驗結果，我覺得有點沮喪	5	4	3	2	1
4.在作實驗時，老師沒有提供足夠的線索給我	5	4	3	2	1
5.因為老師對這些實驗的解釋很含糊，使我不確定要 如何作實驗	5	4	3	2	1
6.這些實驗對我而言很困難	5	4	3	2	1
7.從這種類型的實驗中學習效率比傳統的實驗課差很多	5	4	3	2	1
8.從這些實驗中，我只學到實驗操作的技巧	5	4	3	2	1
9.我從這些實驗中，學到了一些觀念	5	4	3	2	1
10.這些實驗可以用理論課來取代	5	4	3	2	1
11.這些實驗很浪費時間	5	4	3	2	1
12.這些實驗很值得去作	5	4	3	2	1
13.這些實驗與我的日常生活有關	5	4	3	2	1
14.我作這些實驗必須應用到從前學到的東西	5	4	3	2	1
15.我會把我從這些實驗中所學到的技巧轉移到我的日常 生活中	5	4	3	2	1
16. 我需要和組內成員討論與協商，以完成這些實驗	5	4	3	2	1
17.這些實驗加強我設計實驗的能力	5	4	3	2	1
18.這些實驗加強我解釋實驗的能力	5	4	3	2	1
19.這些實驗促進我的創造力和主動性	5	4	3	2	1
20.這些實驗加強我學習生物知識	5	4	3	2	1
21.這些實驗增加我作實驗的自信	5	4	3	2	1
22.這些實驗促使我了解什麼科學家如何作研究	5	4	3	2	1
23.這些實驗刺激我的思考	5	4	3	2	1

24. 這些實驗對我而言，是很有挑戰性的工作 5 4 3 2 1
25. 我對「開放式實驗」的滿意程度是 5 4 3 2 1
26. 「開放式實驗」可行嗎?請說明理由。

Appendix 11

Student Planning Sheet

Appendix 11.1: Task 1. Observation of plant and animal cells

Activity: Observe the living thing you have brought and the following living things which are on the laboratory desk. There are; Elodea, epidermis of long-life flower's leaf, blood cells and paramecium. Draw and compare their similarities and differences.

Hint: (1) The adjustment of diaphragm and focus knob.
(2) The thickness of samples.

Guide to the investigation: Think about:

1. What am I trying to do?
2. Is there any background knowledge I should consider? How can I find it?
3. What types of living thing I am going to observe?
4. What level of living things (organ, tissue, cell....) could I observe under microscope? Why?
5. What factors do I need to think about?
6. How am I going to deal with the living things? What equipment do I need?
7. In terms of the features of the objects, what do I need to record and draw?
8. How am I going to present my results? Do I need to draw up a table?

Appendix 11.2: Task 2. Which one is better?

Activity: Mary is on a diet so as to become thinner. In terms of that, which one of the following fruits do you think is better for her? Grapefruit, orange, tomato or watermelon? Please design an experiment to help Mary in making a better choice.

Information:

1. The ingredients of four fruits (see given table)
2. Benedict Solution reacts with reducing sugar (monosaccharide and polysaccharide which contain aldose or ketose and can react with Fehling's Solution), if present, to form a coloured precipitate. Benedict Solution, when mixed with sugar and heated in a water bath, will change colour from blue to

green to yellow to reddish-orange, depending on the amount of sugar present in the sample.

Guides to the investigation: Think about:

1. What am I trying to do?
2. Is there any background knowledge I should consider? How can I find it?
3. What is going to be the independent variable (i.e. the one I am going to manage)? What is the dependent variable (i.e. the one I am going to measure changing)? What variables have to stay constant (i.e. which ones am I going to control)?
4. How am I going to deal with the samples? What equipment do I need?
5. What sort of measurements (mass, volume, colour change...) will I need to do? How often do I need to take the measurements? How many times should I repeat the experiment?
6. How am I going to present my results? Do I need to draw up a table or graph?

Appendix 11.3: Task 3. Enzyme activity of plant and animal tissues

Information: An enzyme such as catalase (found in peroxisome of living cells) is a protein molecule. It is used for removing Hydrogen Peroxide (H_2O_2) from the cells. Hydrogen Peroxide is the poisonous by-product of metabolism generated by most living cells including human cells. But do not worry too much. Catalase of living cell can speed up the decomposition of Hydrogen Peroxide to water and gas. The amount of gas indicates the amount of catalase of the living material.

- Find out:** (1) What gas is produced when catalase is introduced into Hydrogen Peroxide?
- (2) Which of the following living materials - pork livers, carrots, cucumbers and potatoes have the most catalase?
 - (3) Could I boil the living tissue to keep it for a longer time but not affect the activity of catalase? How can that be proved?

Hint: (1) Consider the amount of the living material which you use and the surface area of this which will react with catalase.

(2) Catalase decomposes H_2O_2 very fast. To avoid the gas given off, you could use syringes and Blue-Tak.

Guides to the investigation: Think about:

1. What am I trying to do?
2. Is there any background knowledge I should consider? How can I find it?
3. What is going to be the independent variable (i.e. the one I am going to manage)? What is the dependent variable (i.e. the one I am going to measure changing)? What variables have to stay constant (i.e. which ones am I going to control)?
4. How am I going to deal with the living things? What equipment do I need?
5. What sort of measurements (mass, volume...) will I need to do? How often do I need to take the measurements? How many times should I repeat the experiment?
6. How am I going to present my results? Do I need to draw up a table or graph?
7. Give the examples where you could apply what you have learned from this investigation to daily life.

實驗一、觀察植物和動物細胞

活動：觀察你所帶來及放在實驗桌上的生物個體或組織：水蘊草、長壽花的表皮、血液、草履蟲。畫出並比較它們的相似及差異處。

提示：(1) 調整光圈和反光鏡

(2) 標本的厚度

實驗指導（想想看）：

- 1.我要作什麼（用自己的話，把今天的實驗要作什麼，再寫一次）？
- 2.有沒有以前所學的知識，我現在可以用得上的？那些知識在哪裡？
- 3.我要觀察哪一種生物？
- 4.在顯微鏡下，我可以觀察到生物的哪一層次(器官、組織、細胞)？為什麼？
- 5.我需要考慮哪些因子？
- 6.我要怎麼處理欲觀察的生物？我需要什麼器材？
- 7.根據所觀察生物的特徵，我該記錄及畫出哪些特徵？
- 8.我該如何呈現我的報告？我需不需要畫張表？

實驗二、什麼比較好？

活動：美美爲了要有苗條的身材而減肥，你認爲下列哪種水果較適合她？葡萄、柚、柳橙、蕃茄或西瓜？請設計一個實驗，來幫助她作較好的選擇。

資訊：(1)四種水果的營養成分(見老師發的營養成分表)

(2)本氏液可和還原糖(含酮基或醛基的單糖和多糖，可和菲林試液產生反應)形成有色沉澱。當本氏液和還原糖混合並在水浴中加熱時，會改變顏色，顏色視待測物中還原糖的含量而定，從藍轉綠、轉黃、再轉成橙紅色。

實驗指導（想想看）：

- 1.我要先作什麼（用自己的話，把今天的實驗要作什麼，再寫一次）？
- 2.有沒有以前所學的知識，我現在可以用得上的？那些知識在哪裡？

- 3.什麼是獨立變因(也就是我要操作的變因)?什麼是依變變因(也就是我要測量它的變化的變因)?什麼變因要保持不變(也就是我要控制的變因)?
- 4.我要如何處理葡萄柚、柳橙、蕃茄和西瓜?我需要什麼器材?
- 5.我需要測量什麼(重量、體積、顏色變化...)?多久要測量一次?這個實驗要重複幾次?
- 6.我該如何呈現我的報告?我需不需要畫張表或作圖?

實驗三、植物和動物組織的酵素活性

資訊：觸酶常見於活細胞的微粒體中，是由蛋白質組成的酵素，它是用來移除細胞中的過氧化氫(H_2O_2)。過氧化氫是體內細胞進行代謝作用時，所產生的副產物，對細胞有害，不過別擔心，生物體內都有觸酶，能將過氧化氫迅速分解成水和某種氣體，同時這種氣體的產生的量，意味著觸酶在活細胞中含量的多寡。

- 活動：**
- 1.當觸酶加入過氧化氫時，哪種氣體會產生？
 - 2.豬肝、胡蘿蔔、黃瓜和馬鈴薯，何者含有最多的觸酶？
 - 3.爲了使這些酵素保存久一點，可否將待測物高溫殺菌，但不影響觸酶活性，請用實驗證明。

- 提示：**
- 1.考慮所用待測物的量及與觸酶作用的表面積。
 - 2.觸酶分解過氧化氫的速度很快，爲了避免氣體逸出，你可以用針筒和 Blue Tak（如次頁附圖所示）。

實驗指導（想想看）：

- 1.我要先作什麼（用自己的話，把今天的實驗要作什麼，再寫一次）？
- 2.有沒有以前所學的知識，我現在可以用得上的？那些知識在哪裡？
- 3.什麼是獨立變因（也就是我要操作的變因）？什麼是依變變因（也就是我要測量它的變化的變因）？什麼變因要保持不變（也就是我要控制的變因）？
- 4.我要如何處理豬肝、胡蘿蔔、黃瓜和馬鈴薯，？我需要什麼器材？
- 5.我需要測量什麼（重量、體積、濃度...）？多久要測量一次？這個實驗要重複幾次？

- 6.我該如何呈現我的報告？我需不需要畫張表或作圖？
- 7.請舉出本實驗所學，亦可應用到生活中的例子。

Appendix 12

Student Self-Evaluation Sheet

1. Title of investigation:
2. How well do I think I carried out this investigation? (Proud of, should be improved)
3. When I was carrying out this investigation, what more would I have liked to know?
4. What do I think I have learned today?
5. What are my findings? Are they different from what I thought would happen? What have I found that I did not know before? How can they be explained?
6. Where do I think the sources of error come from? How am I sure?
7. Do I have any questions about things I don't understand yet?
8. What are the differences between this investigation and the previous one?
9. What do I like and dislike about this investigation? Why?
10. Suggestions for improvement of this investigation.

學生自我評鑑表

1. 實驗名稱
2. 我覺得這個實驗我做得如何? (引以為傲的、應該改善的)
3. 我做這個實驗時，還有什麼我想知道的?
4. 我覺得今天學到了?
5. 我的發現是?它們是否和我預期會發生的不一樣?我發現了什麼，是我以前不知道的?要如何解釋它們?
6. 我認為誤差是來自於?我如何確定?
7. 關於我所不懂的，我有何問題要提出?
8. 這個實驗和以前的實驗有何不同?
9. 這個實驗我喜歡?不喜歡?為什麼?
10. 關於改善這個實驗，我的建議是?

Appendix 13

Homework for interactive teaching

1. Ask your Mom to buy a fresh chicken. Compare it with the animal tissues we have mentioned in biology class. Describe the tissues you seeing and not seeing.
2. Your math teacher is pregnant now, what nutrition do you think she needs especially? Why?
3. Please look for someone's (your parents' or relatives'....) cholesterol examination report. List the detail data (triacid-glycerol ester, high-density lipoprotein...) and check whether he/she has normal cholesterol. If it is abnormal, how can it be improved? What is the mechanism?
4. The colour of a cut apple or potato exposed in the air will turn to dark brown. How can this be prevented? What is the mechanism?
5. In terms of what you have learned in Lesson 3, explain why certain wheat has cold-resistant ability in winter?
6. Please compare the differences between the cell membrane and cell nucleic membrane.
7. Find some diseases which are caused by organelle deficiency. Give reasons.
8. What other functions do cytoskeletons have?
9. What are your opinions of the interactive teaching?

互動式教學作業

1. 請媽媽買一隻新鮮尚未烹調的雞，把牠和我們上課提到的動物組織作個比較，寫下你看到的及未看到的組織。
2. 數學老師懷孕了，妳(你)認為她特別需要哪種營養？為什麼？
3. 請找一個人(父母、親戚...)的膽固醇檢驗報告，將分項數據(三酸甘油脂、高膽固醇密度...)列出，並分析其膽固醇含量是否正常？若不正常？應從何作起，才能改善？
4. 切開的蘋果或馬鈴薯，曝露在空氣中會轉變成深咖啡色，如何避免？原理為何？
5. 根據妳(你)在生物課所學有關脂質的概念，解釋何以某些小麥在冬天有抗寒的能力？
6. 試比較細胞膜和核膜的異同。
7. 試舉出由於胞器有缺陷而引起的疾病，請解釋原因。
8. 細胞骨架還有些什麼功能？
9. 妳(你)對互動式教學的看法如何？

Appendix 14

Pre- and Post-test

Appendix 14.1: Pre-test

1. The following organelles play important roles in synthesizing new substances and decomposing old ones, except (a) RER (Rough Endoplasmic Reticulum) (b) Golgi body (c) lysosome (d) ribosome (e) cytoskeleton
2. Which of the following cells has no nucleus? (a) nerve cell (b) frog's erythrocyte (c) Ecoli's cell (d) muscle cell (e) osteocyte
3. Which of the following structures could not transcribe RNA? (a) mitochondria (b) Golgi body (c) chloroplast (d) nucleus (e) none of above
4. Which of the following statements is incorrect? (a) The salty prunes are preserved in hypertonic solution. (b) The water is a kind of hypotonic solution to the flowers which are dipped in it. (c) I.V. injection is a kind of isotonic solution to the human body. (d) The mechanism of red wine production is osmosis. (e) Blood is a kind of isotonic solution to blood cells.
5. Which of the following organism, its cell composition of cell wall is different from others? (a) onion (b) Elodea (c) mushroom (d) spinach (e) lettuce
6. Which of the following cells are different from others in tissue level? (a) blood cell (b) nerve cell (c) bone cell (d) phagocytic cell (e) fat cell
7. While studying a cell with the electron microscope, a scientist notes the following: numerous ribosomes, a well developed endoplasmic reticulum, chloroplast and a cell wall. What organism is most likely the source of this cell? (a) a fungi (b) an animal (c) a bacterium (d) a plant. (e) a virus
8. Cyanide, a metabolic poison, interferes with the cellular aerobic production of ATP. Which cell organelle does cyanide most directly influence first in this situation? (a) nucleus (b) lysosome (c) mitochondria (d) ribosome (e) endoplasmic reticulum
9. The structure surrounding and selectively regulating the flow of materials from the control centre of the cell is the (a) vacuole (b) nuclear membrane (c) cell membrane (d) lysosome (e) nucleolus
10. Our brain cells cannot lack glucose, even for a very short period of time. Based on the description, what kind of movement of glucose is most likely

- across the membrane of brain cell? (a) facilitated transport (b) diffusion (c) active transport (d) pinocytosis (e) osmosis
11. What molecule type contains nitrogen atoms? (a) carbohydrates (b) lipids (c) amino acids (d) sugar (e) glycerol
 12. Complex chains (highly branched) of glucose molecules stored in our liver and muscle cells is comprised of a molecule known as (a) cellulose (b) lactic acid (c) glycogen (d) sucrose (e) starch
 13. Which of the following statements about cell membrane is correct? The cell membrane is: (a) about 1mm in thickness (b) also called plasmalemma (c) constituted by two 'unit membrane' (d) identical to nuclear membrane (e) the outermost layer of a bacterium
 14. During enzymatic dehydration synthesis reactions, (a) water is added to the molecule acted upon by the enzyme (b) two molecules are usually joined together (c) oxidation occurs (d) energy is released (e) none of the above
 15. Phagocytic cells, such as white blood cell and macrophage that engulf and destroy bacteria would be expected to have many: (a) Golgi bodies (b) mitochondria (c) endoplasmic reticulum (d) nucleoli (e) lysosome.
 16. Cell membrane proteins include: (a) receptor proteins that interact with hormone (b) self-recognition proteins that identify a cell as belonging to the organism itself (c) molecular transport proteins (d) enzyme (e) all of the above
 17. What type of molecular cell membrane transport uses a cell membrane protein but no ATP energy? (a) simple diffusion (b) facilitated diffusion (c) active transport (d) pinocytosis (e) none of the above
 18. Substances are not soluble in water, because that they: (a) are hydrophilic (b) are hydrophobic (c) have polarity (d) could form H bond (e) have unpaired electron
 19. Which of the following physiological functions is unrelated to mineral salts? (a) acting as buffer (b) muscle contraction (c) energy supply (d) blood clotting (e) 'messages' traveling through the nervous system
 20. Which chemical bond is broken in the process of protein hydrolysis? (a) C-N (b) C=O (c) C-H (d) N-H (e) C-OH
 21. Which of the following statements about protein is incorrect? (a) The closer the blood relationship between organisms, the more similar the structure of protein. (b) Protein is the main energy resource of cell. (c) The factors which

affect the character of protein also affect the character of enzyme. (d) Protein could act as a buffer. (e) Protein is the largest amount of organic substance of a cell.

22. Which of the following statements about nerve tissues is correct? (a) A neuron is the nucleus of a nerve cell. (b) The ganglia cell functions as support and nutrient supply for the nerve cell. (c) Dendrite is the short and branched ending of a nerve cell. (d) The nerve cell is a specialized cell without a cell membrane. (e) Only a vertebrate has nerve cells.
23. Which of the following statements about epidermal cells of plant is incorrect? Epidermal cells: (a) have the function of support (b) have the function of secretion (c) have the function of protection (d) have stomata in the epidermis of leaf (e) form root hairs on the outermost of a root
24. Which of the following statements about vascular tissues is correct? (a) Vessel members, tracheids and sieve tube members are live cells, but companion cells are dead ones. (b) Their main function is cell division. (c) Companion cells could transport organic substances. (d) There are perforation plates between the vessel members. (e) Pits are on the surfaces of vessel members, tracheids and sieve tube members.
25. Which part of a plant doesn't have the ability of cell division? (a) vascular cambium (b) stem apical meristems (c) root apical meristems (d) endodermis of root (e) pericycle of the root.

前試

- 1.下列胞器在合成新物質、分解舊物質的過程中，扮演重要角色，除了(A)粗糙內質網 (B)高基氏體 (C)溶體 (D)核糖體 (E)細胞骨架
- 2.下列哪一細胞沒有核？(A)神經細胞 (B)青蛙紅血球 (C)大腸桿菌 (D)肌肉細胞 (E)硬骨細胞
- 3.下列哪一構造無法轉錄 RNA? (A)粒線體 (B)高基氏體 (C)葉綠體 (D)細胞核 (E)以上皆非
- 4.下列哪一敘述不正確？(A)醃梅是保存在高張溶液中 (B)把鮮花插在水中，對花而言，水是低張溶液 (C)靜脈注射液對人體而言，是一種等張溶液 (D)紅酒是利用「滲透」的原理製造出來的 (E)對血球細胞而言，血液是一種等張溶液
- 5.下列哪一細胞，細胞壁的組成成分，與其它細胞不同？(A)洋蔥 (B)水蘊草 (C)洋菇 (D)菠菜 (E)萵苣
- 6.下列哪一細胞，在組織的體制上(屬於哪一種組織)，與其它細胞不同？(A)血球細胞 (B)神經細胞 (C)硬骨細胞 (D)吞噬細胞 (E)脂肪細胞
- 7.有一科學家在使用電子顯微鏡研究細胞時，看到下列構造：細胞壁、很多核糖體、葉綠體、發達的內質網。他所看到的細胞可能來自(A)一種真菌 (B)一種動物 (C)一種細菌 (D)一種植物 (E)一種病毒
- 8.氰化物是一種影響代謝的有毒物質，會干擾細胞行有氧呼吸產生ATP。在此狀況下，氰化物第一個最直接影響的胞器是(A)細胞核 (B)溶體 (C)粒線體 (D)核糖體 (E)內質網
- 9.包圍在細胞的控制中心外面，並可選擇性調節物質從其輸出的構造是(A)液泡 (B)核膜 (C)細胞膜 (D)溶體 (E)核仁
- 10.人類的腦細胞不能缺葡萄糖，即使是很短的時間。基於以上敘述，腦細胞很可能使用哪種方式協助葡萄糖通過細胞膜？(A)便利性運輸 (B)擴散 (C)主動運輸 (D)胞飲 (E)滲透
- 11.下列哪一化合物含有氮原子？(A)碳水化合物 (B)脂質 (C)胺基酸 (D)糖 (E)甘油
- 12.葡萄糖以複雜長鏈(多分支)的方式所形成的分子，儲存在肝與肌肉細胞的是(A)纖維素 (B)乳酸 (C)肝糖 (D)蔗糖 (E)澱粉

- 13.關於細胞膜的敘述，下列何者正確？(A)厚度大約 1mm (B)又稱為原生質膜 (C)由兩個單位膜所組成 (D)和核膜一樣 (E)是細菌細胞最外一層
- 14.在酵素的脫水合成反應中(A)水需加到酵素要作用的分子上 (B)兩個分子會被結合在一起 (C)發生氧化反應 (D)釋能 (E)以上皆非
- 15.吞噬細胞如白血球、巨噬細胞，會包住細菌並摧毀它，這種細胞會有很多(A)高基氏體 (B)粒線體 (C)內質網 (D)細胞核 (E)溶體
- 16.細胞膜蛋白質，包括(A)與激素作用的受體蛋白 (B)可鑑定屬於生物體自己的細胞的自我辨識蛋白 (C)分子運輸蛋白 (D)酵素(E)以上皆是
- 17.哪一種細胞膜上的分子運輸，會用到細胞膜蛋白質，但不需要 ATP？(A)簡單擴散 (B)便利性擴散 (C)主動運輸 (D)胞飲作用 (E)以上皆非
- 18.物質之所以不溶於水，是因為它們(A)具親水性 (B)具忌水性 (C)有極性(D)可形成氫鍵(E)有未成對電子
- 19.下列哪一項不是無機鹽的生理功能？(A)作為緩衝劑 (B)肌肉收縮 (C)供應能量 (D)血液凝固 (E)神經訊息的傳導
- 20.蛋白質水解的過程中，何處的化學鍵被打斷？(A)C-N (B)C=O (C)C-H (D)N-H (E)C-OH
- 21.下列有關蛋白質的敘述，何者錯誤？(A)生物親緣關係越接近，蛋白質的構造也越相似 (B)蛋白質是細胞內主要供應能量的來源 (C)影響蛋白質特性的因素，也影響酵素的特性 (D)蛋白質可當緩衝劑 (E)蛋白質是細胞內最多的有機化合物
- 22.下列有關神經組織的敘述，何者正確？(A)神經元是指神經細胞的細胞核 (B)神經膠細胞的功能，是支持與提供營養給與神經元 (C)樹突是指神經細胞短而呈樹枝狀的末梢 (D)神經細胞是一種不具細胞膜的特化細胞 (E)只有脊椎動物有神經細胞
- 23.下列有關植物表皮組織的敘述，何者錯誤？(A)有支持的功能 (B)有分泌的功能 (C)有保護的功能 (D)葉的表皮組織有氣孔 (E)根的表皮細胞，在根的最外層形成根毛
- 24.下列有關維管組織的敘述，何者正確？(A)導管、假導管、篩管是死細胞，伴細胞是活細胞 (B)主要功能是行細胞分裂 (C)伴細胞能運送有機物

質 (D)導管細胞相連處有孔狀的細胞壁 (E)導管、假導管和篩管細胞表面都有壁孔

25. 哪些部位的細胞不具有分生能力？(A)維管束形成層 (B)莖頂端分生組織 (C)根尖分生組織 (D)根的內皮 (E)根的周鞘

Appendix 14.2: Post-test

1. For breakfast John likes jam, which was made of fresh strawberries by his mum, because the jam his mum makes is not too sweet. If (i) represents monosaccharide (ii) represents disaccharide (iii) polysaccharide the jam contains (a) only (i) (b) only (ii) (c) only (ii) and (iii) (d) only (i) and (ii) (e) (i), (ii) and (iii).
2. Judy and Albert proposed some statements about cooking oils. Please point out which one is wrong. (a) Cooking oils tend to be solid or liquid irrelevant to the existence of double bonds. (b) The cooking oils we select should contain essential fatty acids. (c) Margarine is made by adding hydrogen atoms and removing double bonds. (d) Olive oil is the only suitable cooking oil based on the reasons of nutrient and health. (e) The cooking oils which contain much saturated fatty acid should be used with less frequency.
3. Which of the following statements about how a dividing plant cell forms its cell wall is correct? (a) A plant cell divides into two without cell plate formation cellulose. (b) Between two dividing cells vesicles arising from Golgi body fuse to form a cell plate and cellulose is added to both sides of the cell plate to form primary wall. (c) A plant cell loses its cell wall and then divides into two daughter cells. The daughter cell secretes glucose to the cell outside to develop primary walls. (d) All of the above. (e) None of the above.
4. The detail of the concentration of cholesterol in Mary's blood is in the following table. According the table, Mary should: (a) do regular follow up (b) take medicine for decreasing cholesterol immediately (c) take medicine for decreasing fatty acid in blood immediately (d) stop taking any food containing cholesterol (e) become a vegetarian

Check item	Mary's result	Regular value
Cholesterol	203	130-200
Triglyceride	50	35-160
High Density Lipoprotein	65	Male: > 35 Female: > 60
Low Density Lipoprotein	118	< 130-160

5. Which of the following physiological functions does not belong to membrane

- protein? (a) Has a binding site for hormones to produce reaction. (b) Proceed active transportation. (c) Isolate the cell. (d) Selectively control substance entering a cell. (e) Contact with other cells.
6. Which of the following statements about cell membrane is correct? (a) The selectivity of cell membrane depends on the active transportation of protein. (b) Whether a molecule can pass cell membrane or not depends on the polarity of molecule. (c) A cell membrane has phospholipids and protein, which is similar to the membrane of mitochondria, endoplasmic reticulum and ribosome. (d) There are cholesterol on cell membrane to increase the stability of membrane. (e) The concentration of solute inside the cell membrane is lower than outside and will not generate the pressure of osmosis.
 7. 'The nucleus is the control centre of a cell'. To this statement, which of the following descriptions is more appropriate? (a) Right, because there is DNA in a nucleus, which can produce protein. (b) Wrong, because cell membrane is more important than the nucleus. (c) Right, because the product of transcription in a nucleus can be transported out of the nucleus and precede translation in cytoplasm to produce structural and functional protein. (d) Wrong, because if a nucleus is removed, there is no influence on the cell's living. (e) Right, because the nuclear membrane of a nucleus only allows small molecule to pass rather than big molecule.
 8. The chloroplasts of a plant cell (a) synthesize ATP by H^+ driven chemosmosis (b) have their own DNA, but have no ribosome (c) can produce all the protein they need (d) contain photosynthetic pigments including chlorophyll, carotenes, anthocyanin and xanthophylls (e) exist in any organism which has the ability of photosynthesis
 9. Please compare the differences of a mitochondria and a chloroplast and indicate which of the following is wrong.

Organelle	Chloroplast	Mitochondria
The production of ATP	(a) Has	Has
Self-division	(b) Has	Has
Electron-transport system	(c) Has	Has
Double membrane	(d) Has	Has
Metabolism	(e) Assimilation	Assimilation

10. The formation of which of the following structure or organelle is irrelevant to the cytomembrane system? (a) endoplasmic reticulum (b) ribosome (c) lysosome (d) Golgi body (e) nuclear membrane
11. A human fetus webbed hand turns into five fingers. Which of the following organelles is most related to this statement? (a) mitochondria (b) Golgi body (c) lysosome (d) endoplasmic reticulum (e) ribosome
12. Which of the following substances or reactions does not exist or happen on the thylakoid of chloroplast? (a) photosynthetic pigments (b) photosystem (c) water molecule decomposing reaction (photolysis) (d) carbon dioxide molecule synthesizes glucose (e) the generation of NADPH
13. Which of the following statements about an animal or a plant cell is correct? (a) Different tissue of the same species of plant has different cell shapes. (b) Plant epidermal cells are a regular shape and those of animal are irregular. (c) In different species of plant, the size of epidermal cells is similar. (d) The most difference between an animal and a plant cell is that the former one can move but the latter cannot move. (e) An animal cell has no vacuole.
14. Which of the following statements is not demonstrated by the catalase experiment? (a) Catalase can help organism decompose the toxic substance— H_2O_2 which is produced by metabolic reaction (b) Both animals and plants have catalase (c) The activity of catalase can be detected by the amount of oxygen which is produced by adding H_2O_2 (d) Adding H_2O_2 into ground pork liver leads to reaction releasing heat (e) Catalase existing in living material will not be affected by temperature.
15. Parenchyma means (a) apical meristem at shoot and root tips (b) the cells right under the epidermis of the celery leaf stalk (c) the stone cell of the pear (d) the cells inside the potato tuber (e) guard cells of the leaf
16. The cells of animal connective tissue have many structures and therefore have the following different functions: except for (a) supporting (b) absorbing (c) defending (d) connecting (e) storing
17. Choose a main structure to discriminate an animal and a plant cell. (a) cell wall (b) chloroplast (c) vacuole (d) mitochondria (e) centriole
18. Transport protein and enzyme have many similar characters. Which of the following statements about them is not true? (a) Both of them have substrate

- specificity. (b) Both of them have structure similar to an active site. (c) When there are molecules or ions existing with similar structures, the binding of transport protein and substrate will be inhibited. (d) The number of molecules or ions which a transport protein in a cell can transport is limited within a unit time. (e) Both of them have the function of catalysis.
19. Which of the following statements about lipid is correct? (a) On cell membrane, the hydrophilic end of the lipid is inside and the hydrophobic is outside. (b) Phospholipid consists of only glycerol and fatty acid. (c) Cholesterol is a kind of lipid. (d) Lipid consists of C、H、O、N、P. (e) There are 1-4 double-bonds in saturated fatty acid.
20. Which of the following statements about vitamins is correct? (a) Plant obtains necessary minerals and vitamins from fertilizers. (b) Animals cannot synthesize vitamins. (c) In vitamins, only C and E can help cells to resist free radical. (d) Most of the vitamin B complex has the function of a co-enzyme. (e) If people take too much vitamin from food, these vitamins will be excreted with water.
21. Human and gorilla are regarded as different species because: (a) the constitution of a nucleotide is different (b) the nitrogen base of nucleic acid has different type, number or order (c) the constitution of a amino acid is different (d) the type of monosaccharide is different (e) the type of lipid is different
22. The attraction between water molecules cannot explain water's (a) coherence (b) high specific heat (c) high boiling point (d) polarity (e) surface tension
23. Which of the following statements about inorganic salt is wrong? (a) The amount of inorganic salt human needs is little. (b) Paul's mother has anemia. She should take some chalybeate. (c) Potassium ions involve cell moving and division in human body. (d) Many inorganic ions can form salt as a buffer to maintain the equilibrium of acid and base. (e) Bill's grandmother has osteoporosis. She should take more calcium.
24. Which of the following statements about carbohydrate is correct? (a) There are only three-carbon, five-carbon and six-carbon sugar in monosaccharide. (b) The carbohydrate in grapes is glucose only. (c) The process of monosaccharide synthesizing disaccharide will release energy. (d) The

molecular formula of glucose, fructose and gal-lactose is the same as $C_6H_{12}O_6$.

(e) Disaccharide is formed by the dehydration of two glucose molecules.

25. Which of the following statements about protein is correct? (a) It is the main source of energy supply in human body. (b) It is hydrophobic. (c) It is responsible for substances passing through cell membrane and contact with surroundings. (d) It is on the cell membrane and isolates the cell. (e) Collagen helps moving.

後試:

- 1.大明早餐喜歡吃媽媽用新鮮草莓作的果醬，因為媽媽作的果醬不會太甜而覺得膩。若(1)代表單醣 (2)代表雙醣 (3)代表多醣，則此果醬中含(A)只有 1 (B)只有 2 (C)只有 2 和 3 (D)只有 1 和 2 (E)1、2、3 都有
- 2.萱萱和啓明對食用油的看法不一，以下是他們的觀點。請你選出錯誤的敘述：(A)食用油是液態或固態與雙鍵的有無有關 (B)我們選用的食用油中應要有含必須脂肪酸的油品 (C)植物奶油可能是加入氫去除雙鍵才使它變成固態 (D)基於營養和健康的理由，橄欖油是我們惟一最適合食用的油 (E)含飽和脂肪酸多的食用油應少用
- 3.關於分裂中的細胞是如何形成細胞壁的，下列何者敘述正確？(A)一個植物細胞分裂為二，沒有細胞板形成 (B)一分為二的植物細胞，分別以舊有的細胞壁為基礎，高基氏體分泌小泡在中間愈合，形成分隔，在此分隔旁再加纖維素成為初生細胞壁 (C)一個植物細胞先失去細胞壁，再分裂為二，分裂好的細胞，分別分泌葡萄糖到細胞膜外，然後形成初生細胞壁(D)以上皆是 (E)以上皆非
- 4.某人檢驗血中膽固醇，結果如下表。則該病人應(A)再定期追蹤(B)立即服用降膽固醇藥物 (C)立即服用降血脂藥物 (D)禁止攝取含膽固醇的食物 (E)開始吃素

檢查項目	結果	正常值
膽固醇	203	130-200
三酸甘油酯	50	35-160
高密度酯蛋白	65	男：>35 女：>60
低密度酯蛋白	118	<130-160

- 5.下列何者非細胞膜蛋白之生理功能？(A)和激素結合，引起反應 (B)進行主動運輸 (C)隔離細胞 (D)選擇性控制物質進出細胞(E)與其他細胞聯絡
- 6.有關於細胞膜的敘述，下列何者正確？(A)細胞膜的'選擇性'完全要靠蛋白質的主動運輸作用 (B)分子可否通過細胞膜，完全決定於分子的極性 (C)細胞膜和粒線體、內質網、核糖體的膜很類似，都有磷脂和蛋白質 (D)細

胞膜上有膽固醇增加其穩定性 (E)細胞膜內的溶質濃度低於膜外濃度，不會引起滲透壓

7. 「細胞核是細胞的控制中心」，對此說法，你認為下列那一敘述較恰當？
 (A)對的，因為核內有 DNA 製造蛋白質 (B)錯的，因為細胞膜比它更重要 (C)對的，因為核內進行轉錄作用的產物，可運出細胞核，在細胞質內進行轉譯作用，生成構造與功能性蛋白質(D)錯的，因為如果去掉細胞核，對細胞生存並沒有影響(E)對的，因為細胞核的核膜只讓小分子通過，不讓大分子通過
- 8.植物細胞的葉綠體 (A)藉 H^+ 產生化學滲透勢而合成 ATP (B)有自己的 DNA 但無核糖體 (C)可供應本身所需的所有蛋白質 (D)含有光合作用色素，包括葉綠素、胡蘿蔔素、花青素、葉黃素 (E)存在任何具有行光合作用能力的生物體內
9. 試比較粒線體與葉綠體之異同，並指出下列何者錯誤？

胞器	葉綠體	粒線體
生成 ATP	(A) √	√
自行分裂	(B) √	√
電子傳遞鏈	(C) √	√
雙 膜	(D) √	√
新陳代謝	(E)同化作用	同化作用

- 10.下列哪一構造或胞器的形成和內膜系統無關? (A)內質網 (B)核糖體 (C)溶體 (D)高基氏體 (E)核膜
- 11.人類胎兒的手由原為蹼狀，後漸轉變成五根手指，和此關係最密切的胞器是 (A)粒線體 (B)高基氏體 (C)溶體 (D)內質網 (E)核糖體
- 12.在葉綠體的葉綠囊上，沒有(A)光合色素 (B)光系統 (C)水分子分解反應 (光水解) (D) CO_2 合成葡萄糖 (E)NADPH 生成
- 13.關於動、植物細胞的敘述，下列何者正確？(A)同一種植物的不同組織，有不同細胞形態 (B)植物的表皮組織細胞都呈規則狀，動物的皮膜組織細胞都呈不規則狀 (C)不同種植物，其表皮組織細胞大小相似 (D)動、植物細胞最大的不同，是前者會運動，後者則否 (E)動物細胞沒有液胞

14. 下列那一敘述未在‘觸酶’實驗中被證實?(A)觸酶可幫助生物體分解代謝作用產生的有毒物質-H₂O₂ (B)動物和植物都有觸酶 (C)觸酶的活性，可由加入 H₂O₂ 後產生的氧氣得知 (D)在磨碎的豬肝中加入 H₂O₂，會有放熱反應 (E)觸酶存在活組織中，不受溫度影響
15. 所謂薄壁細胞，是指(A)莖頂或根尖的分生組織 (B)芹菜的葉柄表皮正下方的細胞 (C)梨的石細胞 (D)馬鈴薯塊莖內的細胞 (E)葉的保衛細胞
16. 動物結締組織細胞，因有多種構造，而具下列不同功能，除了(A)支持 (B)吸收 (C)防禦 (D)連結 (E)儲存
17. 選擇一個較主要的構造來區分動、植物細胞： (A)細胞壁 (B)葉綠體(C)液泡 (D)粒線體 (E)中心粒
18. 運輸蛋白和酵素有許多相似的性質，關於此二者的敘述下列何者不正確? (A)二者都有受質專一性 (B)二者都有有類似活化位的構造 (C)有構造相似的分子或離子存在時，運輸蛋白和受質結合會受到抑制 (D)在單位時間內，一個細胞上的運輸蛋白所能運送的分子或離子數目也有一定 (E)二者都有有催化反應的功能
19. 關於脂質的敘述，下列何者正確? (A)細胞膜上的脂質，是親水端朝內，厭水端朝外 (B)磷脂僅由甘油和脂肪酸所組成 (C)膽固醇是一種脂質 (D)脂質是由 C, H, O, N, P 所組成 (E)飽和脂肪酸內，通常含有 1~4 個雙鍵
20. 關於維生素的敘述，下列何者正確? (A)植物從肥料中獲取所需的礦物質和維生素 (B)動物沒有能力合成維生素 (C)維生素中只有 C, E 可協助細胞對抗自由基 (D)大多數的 B 群維生素，都有輔酶的功能 (E)人類若從食物中攝取過量維生素，這些維生素都可隨著水分被排除
21. 人和黑猩猩之所以被視為不同種，是因 (A) 組成核苷酸的分子不同 (B)核酸的含氮鹽基的種類、數目或排列順序不同 (C)組成胺基酸的分子不同 (D)單醣分子的種類不同 (E)脂質的種類不同
22. 水分子間的吸引力，不能解釋水的 (A)內聚力 (B)比熱大 (C)沸點高 (D)極性 (E)表面張力
23. 關於無機鹽的敘述，下列何者錯誤? (A)人體所需要的無機鹽的量很少 (B)宜鴻的媽媽有貧血的現象，應該補充些鐵劑 (C)在人體內，鉀離子參

與細胞運動和分裂 (D)很多無機鹽離子可形成鹽類作為緩衝物，以維持酸鹼平衡 (E)敬芳的奶奶有骨質疏鬆的現象，應多補充鈣質

24. 有關醣類的敘述，下列何者是正確的？ (A)單醣只有三碳醣、五碳醣和六碳醣 (B)葡萄裡面的醣類只有葡萄糖 (C)單醣合成雙醣的過程會釋能 (D)葡萄糖、果糖和半乳糖的分子式，都是 $C_6H_{12}O_6$ (E)雙醣是由兩個葡萄糖分子脫水而成
25. 下列有關蛋白質的敘述，何者正確？ (A)是人體內主要能量供應的來源 (B)是厭水性 (C)在細胞膜上負責物質進出和外界的聯絡 (D)位於細胞膜上可隔離細胞 (E)膠原蛋白協助運動

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