An evaluation of the new junior secondary science curriculum in Hong Kong

by

Yeung Chung Lee

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Abstract

This thesis is a critical evaluation of the junior secondary science curriculum reform in Hong Kong. The new curriculum replaces the previous Integrated Science curriculum based on Scottish Integrated Science developed in the 1970s. This study focuses on the context of the reform, the distinctive features of the curriculum, how teachers put it into practice, and evidence of improvement in students' learning outcomes in terms of process skills, attitude toward science, and science self-concept in comparison with the old curriculum.

The new curriculum is evaluated at three levels: the intended, implemented, and achieved curriculum. A multi-method design incorporating documentary analysis, planner interviews, teacher survey and interviews, quasi-experimental study and student interviews is used to collect both qualitative and quantitative data. The consistency of the findings at individual levels is critically examined, and opportunities and problems identified, leading finally to suggestions for improvement.

The findings indicate that the present reform was driven by concerns to meet personal, social and educational needs in contemporary society. The new curriculum departs from the previous one by emphasizing investigation as a unifying theme which characterizes the nature of science, and by focusing on the relevance of science to our everyday lives. As claimed by the planners, a distinctive feature is the inclusion of investigations to bring together students' understanding of concepts and skills, and to further extend them in fairly open situations. The investigative approach was implemented to a limited extent and with great variations among individual teachers. Student outcomes suggest improvement was restricted to less complex process skills, and that student attitudes toward science and science curriculum deteriorated. These outcomes may be attributed to inconsistencies between planners' intentions, the curriculum design, and classroom practices. This study strongly implies that improvement should focus on bringing open investigation to a more central position in the curriculum design, and adopting a more realistic approach in teacher training, aiming to promote role shifting in teachers from a knowledge provider to a facilitator for empowering students to inquire.

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List of abbreviations

AAAS	American Academy for the Advancement of Science
AL	Advanced level
AS	Advanced Supplementary level
ASE	Association for Science Education
CBAM	Concerns Based Adoption Model
CDC/HKCDC	Curriculum Development Committee of Hong Kong
CDI	Curriculum Development Institute of Hong Kong
CMI schools	Schools using Chinese as the medium of instruction
DES/WO	Department of Education and Science and the Welsh Office
DFE/WO	Department for Education and the Welsh Office
DfEE	Department for Education and Employment
EMI schools	Schools using English as the medium of instruction
HKED	Hong Kong Education Department
IEA	Innternational Association for the Evaluation of Educational Achievement
IS	Integrated Science
KLA	Key learning area
NRC	National Research Council
OECD	Organization for Economic Cooperation and Development
QCA	Qualifications and Curriculum Authority
RQ	Research question
S1-3	Secondary 1 to 3
SISP	Scottish Integrated Science Project
SISS	Second International Science Study
STS	Science-Technology-Society
TGAT	Task Group on Assessment and Testing
TIMSS	Third International Mathematics and Science Study

Chapter 1: Introduction

1.1 Rationale for the study

This thesis is a critical evaluation of the new junior science curriculum reform in Hong Kong. The new curriculum was implemented in Secondary 1 to 3 (age 12 to 15) in the year 2000/2001 to replace the old integrated science curriculum, which had been in place since the late 1970s.

My reasons for undertaking this evaluative study are four-fold. First, as a science teacher educator, I find it crucial to understand what implications this reform has for both secondary science education and science teacher education. Second, I am interested in knowing how the reform impacts on Hong Kong students' science achievement after the last two international science studies conducted under the aegis of the International Association for the Evaluation of Educational Achievement (IEA): the Second International Science Study (SISS) in 1984 and the Third International Mathematics and Science Study (TIMSS) in 1995. Hong Kong students fared poorly in both studies, whereas countries like Singapore and England made significant improvements in TIMSS after undertaking extensive curriculum reform. The questions in my mind are, "Could a reform of the Hong Kong science curriculum also hold promise for higher standards of achievements for our students? and Are there other weaknesses inherent in our own system which are reform-proof?"

Third, the design of a junior science curriculum is a new undertaking for Hong Kong. The previous Integrated Science (IS) curriculum was mainly adopted from the Scottish Integrated Science programme developed in the 1970s, with little ownership among local curriculum planners or teachers. Hence, it is important to know whether the new curriculum is more effective than the old one in promoting science learning in the local context. Fourth, Hong Kong has yet to develop a culture for rigorous curriculum evaluation. The present study could contribute to developing this culture. Although the curriculum has already been implemented, this study could still play a formative role by suggesting improvements for future curriculum revisions.

As the school curriculum is essentially a product of society, before elaborating on my research questions, I consider it useful to look into the context of Hong Kong: its culture, education system and its overall curriculum, to provide a basis for analysing the present reform.

1.2 Social, cultural and economic milieu of Hong Kong

1.2.1 The economic and political scene

Hong Kong was a British colony from 1841 to 1997. Over 98% of the 6 million population of Hong Kong are Chinese. In the 1950s, entrepreneurs who fled from China helped to make Hong Kong an industrial city, dominated by light industries. By the 1980s, with most of the manufacturing plants moving to mainland China where costs and labour were much cheaper, Hong Kong had shifted its role from a manufacturing base to a regional financial centre for providing financial services. Its economic framework has remained unchanged despite the return of sovereignty to China since 1997.

Against this historical background, scientific development has never been emphasized in Hong Kong, as this seems not essential to the region's way of life. The history of Hong Kong as a trading port has established its tradition of acquiring resources from mainland China or other countries. There is a certain degree of technological development here, mainly to serve the light industries. The political setting of Hong Kong in the colonial era imposed heavy constraints on the development of scientific research, which is a long-term endeavour and does not guarantee immediate profit. The desire for getting quick return seemed to dominate many Hong Kong people's minds. The title of the book, *Hong Kong: Borrowed Place - Borrowed Time* (Hughes 1968) exemplified vividly the rationale behind this mentality. In the post-colonial era, Hong Kong has acquired the status of a special administrative region of China, with a relatively "independent" political and economic system. This special status obviates the need for Hong Kong to contribute directly to China's national development. Moreover, Hong Kong's place as a financial and servicing centre implies there is no urgent need to develop scientific research to support high-tech industries as in other countries. The major encounter of Hong Kong people with science and technology is at the consumer level where they make use of various kinds of technological artefacts in their daily lives.

1.2.2 The social and cultural setting

Many people came to Hong Kong as refugees from China. They desired to live a peaceful life and to improve the standard of living for their families. In Chinese culture, education is seen as a means for achieving social mobility. The increasing affluence in Hong Kong society raised education to a high priority. Parents' expectation for their children to excel in schools has helped to fuel rote learning which is not conducive to the development of high-order thinking or independent learning. Hong Kong parents respect science because achievement in science is regarded as a gateway to respectable professions like medicine and engineering. A commonly held view is that boys are more suitable for mathematics and science subjects, whereas girls are better in languages and humanities subjects.

1.2.3 The Education System

There are four stages/levels of schooling in Hong Kong: pre-primary, primary, secondary and tertiary. Students study at pre-primary level from age three to six. After that, they attend 6 years of primary education from age six to twelve. Allocation of secondary school places depends on students' internal assessment results in Primary 5 and 6 and the overall performance of their school in a centrally administered scaling test. Secondary education lasts for five years. Most pupils will graduate from school at around seventeen. At the end of Secondary Five, students take the Hong Kong Certificate of Education Examination (HKCEE). After that, students who continue further study may choose the A-Levels for two years in preparation to enter a university, a technical institute or a school of commerce. The normal age for entry to university is nineteen. Since 1978, it has become a legal requirement for all students to complete a 9-year compulsory education, that is, from Primary One to Secondary Three. The present study is focussed on the last three years of compulsory education, i.e. from Secondary 1 to 3.

The medium of instruction in primary schools is Chinese. At the secondary level, the most common medium of instruction was English. This continued until 1998 when the government mandated the "mother-tongue teaching" policy (HKED 1997). From then on, Chinese has been used in about three quarters of secondary schools at S1-3. The remaining one-quarter of schools uses English (English as medium of instruction, EMI). These schools would only admit students who were assessed to be capable of using English to learn. From S4 onwards, schools are free to decide their medium of instruction.

1.2.4 Mechanism for curriculum development

In Hong Kong, the ultimate responsibility for curriculum development rests with the Curriculum Development Council (CDC) which is a non-statutory advisory body, with members appointed by the government. It is supported by the Curriculum Development Institute (CDI) of the Education Department. The roles of the CDI range from initiating curriculum changes and writing syllabuses to monitoring textbooks and providing school-based support. It assumes a key and vital position in curriculum reform in Hong Kong. Hence, the curriculum decision-making process in Hong Kong is described as "centralised" and "centre-periphery" (Morris 1996).

Before 1999, curriculum development was the responsibility of various subject committees, organised at the primary, secondary and advanced levels and the link between different phases was weak. After 1999, the subject committees were restructured into eight Key Learning Area (KLA) Committees, covering eight main areas of study, and the Committee on Science Education is one of them. The restructuring process aimed to streamline the previous structure and to ensure "a broad and balanced curriculum with continuity and coherence at all levels of schooling and their interfaces" (HKCDC 1999, 15.5.1999).

Before restructuring of the CDC, the normal process for reforming a subject curriculum involved four stages. The first stage was the initiation, in which members of the respective subject committees, very often CDI representatives to the committees, initiated changes. Second, the Subject Committee submitted a plan to the committee at higher levels. If the plan was endorsed, the third stage would follow, in which a working group would be set up within that Subject Committee to formulate a detailed plan for change. Finally, a draft syllabus was submitted to the Subject Committee and other higher-level committees for endorsement.

After the CDC's decision, a syllabus was written together with a curriculum guide. In some cases where drastic change was proposed, for instance when a new subject was suggested, a provisional syllabus would first be produced, followed by a trial in selected schools. The trial evaluation would form a basis for further refinements. After that, the revised syllabus would be produced. This was normally followed by the writing of textbooks by commercial publishers with the syllabus as the blueprint. This process of curriculum development has remained basically unchanged after the restructuring of the CDC.

In recent years, the CDI has promoted the concept of "curriculum tailoring". The aim is to enable schools to adapt the official subject curriculum according to the needs of their students, especially for those in the lower ability range. The CDI will send special teams of officers to work together with teachers in their schools to tailor the curriculum to the needs and ability of their students.

1.2.5 The science curriculum

Science at the pre-primary and primary levels

An overview of science curricula at different levels of schooling in Hong Kong is provided in Appendix 1.1. At the pre-primary level, learning is organised around themes, like water, weather, planets, and day and night, some incorporating science. There is no teaching syllabus for science.

In the primary school, science was taught as a separate core subject up to 1996. In 1996, primary science was amalgamated with two other subjects: Health Education and Social Studies, into one single subject - General Studies (HKCDC 1997). This change was based on the belief that students could develop a more holistic picture of the three subjects if they were taught together. Integration of these subjects was thought to be more compatible with students' ways of organising knowledge derived from their life experiences. The curriculum content was divided into four units, namely "Healthy Living", "Living Environment", "Natural World", and "Science and Technology".

Science at the Junior Secondary Level

Science is a core subject from Secondary 1 to 3, which is from age 12 to 15. Before 1975, most secondary schools taught General Science in S1-2 which was divided into Physics, Chemistry and Biology components. In late 1970s to early 1980s, the General Science curriculum was gradually replaced by a new Integrated Science (IS) curriculum adapted from the Scottish Integrated Science programme which emphasized learning through discovery. Assessment at this level is regarded as low-stake. It is administered by individual schools which have freedom to select the modes of assessment although paper-and-pencil test seems to be the rule.

Approximately four to five periods of 40 minutes each are allocated for science each week. Normally, only two to four periods are conducted in the laboratory as there is only one laboratory for junior secondary science in each school. The normal class size in Hong Kong secondary schools is about 40. Junior secondary science teachers may or may not have a science degree. The non-science degree or non-degree holders normally have received training in science teaching before they entered the profession.

Science at senior secondary levels (secondary 4-5 and the sixth forms)

Students are commonly divided into "Art" and "Science" streams from Secondary 4 onward. All students in the Science stream will take the three separate science disciplines: Physics, Chemistry and Biology. For the Art Stream, some schools may offer Human Biology, a narrower version of Biology, which is thought to be more girl-friendly.

In the sixth form, science subjects, including Physics, Chemistry and Biology, are offered at two levels, the Advanced Supplementary (AS) Level and the Advanced Level (AL). The AS subjects have roughly half of the weighting of the corresponding AL subjects. Different schools may offer different combinations of subjects.

1.3 Purposes of the study

With the IS curriculum implemented two decades ago, the CDC decided to plan for a reform in mid 1990s. From a preliminary analysis of the new syllabus, there is a shift in emphasis from guided discovery to the investigative approach. According to the new syllabus (HKCDC 1998), science investigation is treated as a central theme to link the three major content areas (Appendix 1.2). The curriculum content is also made more relevant to students' everyday lives. These changes in curriculum content and approaches are stated explicitly in the 'Introduction' section of the syllabus:

> *"The investigative approach, which involves students in defining problems, designing experiments to find solutions, carrying out practical work and interpreting the results, should be employed. Such investigations would enhance the acquisition of knowledge and skills as well as contribute towards other educational goals such as cultivation of citizenship, development of appropriate social and personal values and appreciation and respect for life. To achieve these ends, it is necessary to link science education to technological applications, social issues, and the daily experiences of students. Learning science in these contexts is more interesting and effective. (HKCDC, 1998, p.2)"*

With these changes in emphasis, it is important to examine the reform at greater depth by studying: how the present reform came about; how it was translated into the official curriculum document; how it impacts on classroom practices, and whether it would lead to improvement in terms of student achievement. This is a tall order for a sole researcher. Hence, the present research is best treated as a small-scale pilot evaluation study, paving the way for further inquiry on a larger scale. The prime goal is to identify opportunities and problems in the first year of implementation, and to inform curriculum planners and teachers on their implications. If this could be achieved, I will consider the study a successful one.

1.4 Research Questions

To focus my research better, I formulate four research questions. The theoretical bases which underpin these research questions will be discussed in detail in Chapter 4. These research questions are listed as follows:-

1. What is the context of the reform and what makes the new curriculum distinct from the previous curriculum?
2. Do teachers implement the new curriculum as intended by curriculum planners, particularly with respect to the use of the investigative approach?
3. Is there any evidence of improvement in students' process skills and attitudes toward science and the science curriculum on completion of the first year of implementation when compared to the old curriculum? To what extent is students' science self-concept influenced by the new curriculum?
4. What are the implications of the research findings for the continued implementation of the new curriculum?

To put the first three research questions to a better focus, the following sub-questions were formulated:

Sub-questions for Research Question 1: Evaluation of the intended curriculum

1.1 What is the context of the reform, and the principles and theoretical underpinnings that guide the development of the new science curriculum?

1.2 How did curriculum planners translate their perceptions for reform into the official curriculum document?

1.3 What similarities and differences between the new and old curricula are apparent?

The methodology for answering these questions is set out in Section 4.4. The findings are described in Chapter 5.

Sub-questions of Research question 2: An evaluation of the implemented curriculum

2.1 How do teachers perceive the new curriculum? To what extent are teachers' perceptions in line with the intended curriculum?

2.2 How does the implemented curriculum differ from the intended curriculum teachers perceive?

2.3 What opportunities and constraints are present? How do they affect implementation?

The methodology for answering these questions is set out in Section 4.5. The findings are described in Chapter 6.

Sub-questions of Research Question 3: An evaluation of the achieved curriculum

3.1 How do students' process skills, attitudes toward science and science curriculum, and science self-concept change in the first year of the implemented curriculum?

3.2 How does the new curriculum compare with the old in terms of the parameters mentioned in Sub-question 3.1?

The methodology for answering these questions is set out in section 4.6. The findings are described in Chapter 7.

1.5 Organization of the thesis

This chapter is followed by a review of literature, which is the focus of Chapter 2 and 3. Chapter 2 reviews the context of science curriculum reforms in the past few decades and discusses the determinants of success and failure. The purpose is to put the reform in Hong Kong in a historical and global perspective, and to bring to light its potential opportunities as well as pitfalls.

Chapter 3 focuses on science curriculum evaluation. It explores different models of curriculum evaluation, with particular emphasis on their strengths and limitations. It also reviews evaluation studies of science curricula to identify the strategies and methods employed, and how their findings illuminate the reforms. This is followed by a critical review of previous science curriculum evaluation studies carried out in Hong Kong to provide a context for the design of the present study.

Chapter 4 details the evaluation framework and the methodology of the study. It discusses how the framework is developed and how the research questions are generated, drawing insights from the review of curriculum reform, evaluation models, and science curriculum evaluation studies. It goes on to discuss how the methodological design fits into the major research paradigms and how it differs from them. It also explains the different methods incorporated into the design, including curriculum analysis, interviews with curriculum planners, teachers and students, teacher surveys, and quasi-experimental study.

The data collected are analyzed and presented in Chapter 5, 6 and 7 to provide the bases for answering the first three research questions. Chapter 5 analyses the data from curriculum analysis and interviews with curriculum planners, thereby answering RQ1. Chapter 6 addresses RQ2 by analyzing the data collected from the teacher survey and teacher interviews. Chapter 7 deals mainly with statistical analyses of the student outcomes reflected by the quasi-experimental study, supplemented with data obtained from student interviews. By comparing the learning outcomes in the new and the old curriculum, the impact of the present curriculum reform could be inferred, hence answering RQ3.

Chapter 8, which is the last chapter, summarizes the empirical findings from Chapters 5 to 7. It focuses particularly on the problems, gaps and constraints, as well as strengths and opportunities identified at different levels of the curriculum process. These provide a basis for discussion on the implications for continued implementation of the new curriculum, as guided by RQ4. This chapter will end with a discussion on the limitations as well as the significance of the study, together with some personal reflections and recommendations for further study.

1.6 Summary

This chapter outlines my intentions for undertaking the present study and the rationale behind. From a historical perspective, Hong Kong had very limited experience in science curriculum reform since the past reform was merely an adoption of a foreign curriculum. The present reform should be viewed against the particular context of Hong Kong where scientific development has not received as much attention as in other countries. Students only receive formal science education beginning from Secondary 1, as science has been integrated with the humanities at the primary level. Curriculum in Hong Kong is highly centralized, hence the present reform belongs to the "center-periphery" type. This makes curriculum evaluation an essential endeavour so that feedback on the outcomes and the implementation process can be channeled to the planners. In the next chapter I will turn to the literature for a review of past science curriculum reforms so that the present reform could be viewed in perspective.

Chapter 2: Science curriculum reform

2.1 Introduction

The review in this chapter focuses on the context of past science curriculum reforms and the lessons learned from these reforms. It contributes to the present study in two ways. First, exploring the context of reform helps to unveil the driving forces behind past reforms. This places the present reform in the context of worldwide developments and illuminates the possible influences leading to its conception. The present study will pinpoint these influences to see whether the reform could live up to the planners' expectations. Second, reviewing the lessons learnt from past reforms brings to light factors determining success and failure of reforms. The understanding of these factors help to bring the present evaluation to a sharper focus by guiding the development of appropriate research strategies. These strategies should be capable of revealing potential factors which may influence the effectiveness of the present reform. As a further step, these factors are used as vantage points for exploring more in-depth issues given the historical, political and socio-cultural uniqueness of Hong Kong.

Before embarking on the review, I consider it useful to clarify the notion of curriculum, which is crucial to my discussion on curriculum reform and evaluation in this chapter and the next.

2.2. Curriculum and curriculum reform

Before attempting to evaluate a curriculum, it is important to clarify the concepts of curriculum and curriculum reforms so as to define clearly the boundary for the evaluation. Tyler (1949) in his seminal paper conceptualizes curriculum as comprising four basic components:

What are the intentions of the curriculum?
What is the content?
How are learning experiences organized?
How are students' learning outcomes assessed?

Tyler's conceptualization has laid the foundation for the subsequent development of ideas concerning the curriculum. According to Fullan (1991), curriculum can be defined as "instructionally related educational experiences of students". Morris (1996) argues that curriculum includes consideration of the purposes of schooling, what we teach, how we teach, both what is planned and unplanned. It can focus on the product of schooling or on its processes.

Connelly and Lantz (1991) analyze a number of definitions of curriculum and categorize them into two major types: "means-end" and the "existential-personal". The former refers to the intended learning outcomes and means for achieving them, fitting into Tyler's paradigm. The latter defines curriculum content by the meaning the instructional situation has for the students. A synthesis of these two dimensions leads to the understanding that the intentions of the curriculum do not necessarily give rise to the intended outcomes due to factors pertaining to the implementation process and to students. Hence, as noted by different researchers (e.g. Cuban 1992; Morris 1996) curriculum could be differentiated into three levels: intended, implemented, and achieved curriculum. This conceptualization of curriculum had been incorporated into the framework of the Second International Science Study (SISS) and the Third International Mathematics and Science Study (TIMSS) (Orpwood and Souque 1985; Holbrook 1989; Robitaille, Schmidt et al. 1993). I consider this conceptualization a useful one in defining the boundary of the curriculum and hence in designing my own framework for curriculum evaluation. I discuss further the meaning of these three levels of curriculum.

The three levels of curriculum

The intended curriculum includes the goals, objectives, learning approaches and activities advocated in official curriculum documents. This level of curriculum reflects the planners' intentions which are largely based on education theories deemed suitable for teaching and learning in general and study of subject disciplines in particular.

The implemented curriculum or the "taught" curriculum is the curriculum which is actually taught by teachers in schools and classrooms. Its major determinant is teachers. Teachers' beliefs would determine how the intended curriculum is implemented. Apart from teachers' decisions about what should be taught, there is an informal side to the implemented curriculum. This includes teachers' expectations for student behaviours and how they handle misbehaviour (Cuban 1992). Evidence shows that there is a gap between the intended and the implemented curriculum, and that teachers' beliefs, practices, professional expertise, and resource constraints are the major sources of variances (Prophet 1990; Baimba, Katterns et al. 1993; Gallard and Gallagher 1994; Jenkins 1995; Russell, Qualter et al. 1995; Hacker and Rowe 1997)

The achieved curriculum represents the curriculum intentions achieved by the learner. This level of curriculum comprises the outcomes of schooling – the concepts, processes, and attitudes that students acquired during schooling (Robitaille, Schmidt et al. 1993), As in the case between the intended and implemented curricula, inconsistency also exists between what is implemented and learnt as evidenced in the findings of evaluation studies (Alexander 1974; Wideen 1975).

In sum, a curriculum is characterized both by its basic components including objectives, contents and method of delivery and means of assessment, and by the levels through which it progresses from planning to the achievement of outcomes.

Curriculum reform

When a curriculum undergoes a major change, it constitutes a reform. Fullan (1991, p.279) concedes that reform is used rather interchangeably with "change", "innovation", or "movement". Yet, he distinguishes curriculum reform as one which "concerns more comprehensive and fundamental curriculum change". By contrast, he argues that curriculum change is more general than curriculum reform, whereas curriculum innovation tends to be more specific. Curriculum movement has "more of an historical connotation and is used to characterize periods of change by their main common themes". Fullan further characterizes reform as change that is based on "major value changes or redirections, and are often initiated in the political system".

Other researchers provide similar views. Paulston (1980, p.301) defines curriculum reform as "attempts to introduce major alterations of content, access, or structure in national educational systems". Like Fullan, he distinguishes innovations from reform in that the former is more localized than the latter.

Rulcker (1991) describes reform as innovation in the educational system with regard to its content. He sees reform as a system that should be accompanied from the outset by the development of a sound theory. He further characterizes curriculum reform as occurring when "innovation comes to the fore with a claim that it is in essence ideological, and is deliberately, purposefully, and methodically carried out". Nevertheless, he concedes that in reality it is often the case that "theory is not well articulated with the practical conditions in various national, regional and local areas of practice" (p.281).

In this thesis, curriculum reform is perceived as a major alteration to the curriculum. It is a purposeful activity, usually guided by theory and values, which is designed to lead the curriculum to a new direction.

2.3 Context of science curriculum reforms

Reviewing the context of past science curriculum reforms should help to guide the study in the present context of Hong Kong. As a starting point, it is useful to take a look at the different perspectives of reforms as synthesized by other researchers in their reviews.

2.3.1 Different perspectives of curriculum reforms

Lawton (1978) analyzes the context of curriculum change from four perspectives: historical, sociological, philosophical and psychological. He argues that most curricula were historical accidents which had developed in "an unsystematic, sometimes almost chaotic, way, generally growing in range of content covered " (Lawton 1978, p272). Hence the existing curriculum is an amalgam of past developments which bears on future developments. He maintains that sociological reasons for changes stem from the need to "socialize the young for their social roles when they leave schools."

Lawton argues that the curriculum should change to let all children have access to the same kinds of knowledge although they will not reach the same level of attainment. It should be "made relevant to modern society but not necessarily subservient to undesirable aspects of it." (Lawton 1978, p277). The third perspective, the philosophical perspective, concerns that students should be exposed to a certain structure of knowledge although what constitutes that essential structure is debatable. However, this is what a balanced curriculum should take into account. Finally, there is also a psychological perspective to curriculum change. This relates to the characteristics of student learning as advocated by psychologists, e.g. Piaget's stage theory. Despite the differences of the four perspectives, Lawton points out that more than one reason may operate at the same time in influencing a reform.

Black and Atkin (1996) identify four main forces for reform in their analysis of twenty-three curriculum projects on science, mathematics and technology in thirteen countries funded by the OECD. First, many reforms are driven by serious concerns about a country's economic competitiveness. Schools are reconsidering new technology-related competencies that students need to acquire to be productive in modern society and which make them more employable. Second, many reforms are to promote science, mathematics and technology education essential for future citizens. The third force is related to the principles of inclusiveness and equity, in respect of abilities, gender, social class, race, culture and languages spoken. Finally, Black and Atkin argue that the foremost justifications for these reforms of science, mathematics and technology education today are based on new conceptions of learning which the reformer hopes to bring into the classroom.

Fensham (1992) carried out an analysis of influences with particular regard to the science curriculum. He argues that the influences on science curriculum reform varied with time. In the 1950s and 1960s, influences were mainly from concerned science teachers, academic scientists, political and economic comparisons, psychological theories of teaching and learning, and philosophical ideas about science and science education. In the years from 1950/60s to 1980s, there were new influences on reform including research outcomes of science educators, results of evaluation of previous curricula, measurements of science educational achievement, major social changes, the inclusions of new groups of learners, and new technologies for learning.

In essence, these researchers try to explain how past reforms came about. In this thesis, I consider it useful to synthesize these various perspectives further with more evidence drawn from contemporary reforms. My review complements previous reviews in three aspects. First, I draw extensively on national science curriculum reforms and curriculum projects that are comparable in scale to the present reform in Hong Kong. Second, I sample reforms from a wider geographical coverage and socio-cultural settings to make my review more representative. Third, I examine the extent to which old driving forces have continued to impact on recent curriculum reforms, and how new forces emerged in the light of new developments in science education toward the 2000s. These forces were likely to bear upon the direction of current or even future reforms. Hence, my aim is to add to our existing understanding of science curriculum reforms and shed light on the background to the present reform. In the following paragraphs, I explore four main contexts for science curriculum reforms: political, economic, personal and social, and educational.

2.3.2 The political context

History shows that the struggle for power within and across nations constituted the major political influences on science curriculum reforms. For example, the "space race" between the USA and the Soviet Union in the 1950s/60s was widely hailed as an important stimulus for the subsequent waves of curriculum reforms. With the persistence of international tension in the post-Sputnik era, the enthusiasm to win out in science education has not faded away, particularly in the US. An influential American document, Educating Americans for the 21st Century (NSF 1983) suggested,

> *"By 1995, the Nation must provide, for all its youth, a level of mathematics, science and technology education that is the finest in the world, without sacrificing the American birthright of personal choice, equity and opportunity." (p.v. of "Executive Summary")*

This mission was incorporated into the 1994 "Educate America" Act. One of the key goals of this Act was to have American students ranked first in international comparisons by the year 2000 (Robeck 1997). This mission strongly implies the continued dominance of political influences on science curriculum reform toward the end of the twentieth century, a period seemingly more chaotic and unpredictable than in the Cold War period. Obviously, there was considerable economic interest associated with it, a point that will be picked up in the next section.

The 1950s developments in the USA had widespread repercussions elsewhere. The UK was stimulated to launch the Nuffield Science Teaching Projects in the 1960s. Nuffield projects had an important place in their times and became the precursors of other science projects in the UK in the following few decades. Both the Nuffield and the American projects were widely spread in the overseas. The Physical Sciences Study Committee (PSSC) was translated into 14 languages for use in other countries (Gunstone 1991). Some of the revised editions of Nuffield projects are still in use today.

Influences of colonialism

Political influences were particularly notable in countries previously under colonial rule. Science curricula were frequently "imported" from colonial powers like Britain to its colonies (Prophet 1990; Lee 1992). Despite these colonies achieving independence towards the end of twentieth century, foreign influence persisted such that "curriculum reforms" amounted to the adoption of western curriculum package. For example, Zainal (1988) explains why Malaysia adopted Nuffield and Integrated Science. First, this was seen as essential to maintain continuity in the examination system so that students could continue to sit for the Cambridge examinations. Second, financial aid and professional advice and training opportunities for teachers were readily available from Britain. Third, British projects were deemed to be relevant to the Malaysian educational context in terms of its educational goals, educational structure, needs of students, and educational resources, all of which were relics of the former political ties between Britain and Malaysia. Viewed from the perspective of cultural anthropology, Cobern and Aikenhead (1998) argue that science is a western subculture and represents power and progress, therefore it is easy for western science to permeate non-western cultures. Fensham (1992) describes this slavish adoption of western curricula by developing countries outright as "cultural imperialism". As mentioned previously, the old Hong Kong junior secondary science curriculum was adopted directly from the Scottish Integrated Science programme, a very popular project adopted by British colonies at the time.

Control of the curriculum

Political influences are central to reforms which seek to redress the balance in curriculum control in a national context. A prominent case was the enactment of the 1988 Reform Act in England and Wales, paving the way for the promulgation of the National Curriculum. Before this, there was a great degree of autonomy for English and Welch schools to plan their own curriculum as long as students met certification requirements at the end of secondary schooling. The recent reform could be viewed as a political move to centralize curriculum control. As Donnelly and Jenkins (2001) argue, one reason was that the government saw past practices as contributing to the alleged decline in the standards of education and teaching. They wrote:

> *"[Teachers] among others, were held responsible for the development and teaching of politically tainted and intellectually ungrounded subjects (typically, 'peace studies') and for the indiscriminate use of child-centred and progressive methods of teaching..." (Donnelly and Jenkins 2001, p100)*

As a result, the first version of the National Curriculum became statutory for all schools in England and Wales in the late 1980s. Accompanying the curriculum document is a set of criteria specifying the standards to be achieved by students at four age-linked progressive stages (DfEE/QCA 1999). All these could be seen as a shift in curriculum development mechanism from a relatively autonomous mode to a power-coercive mode as described by Hoyle (1970). Donnelly and Jenkins (2001) highlight the political consequences of the reform as follows:

> *"The Act also defined the concept of a core curriculum much more rigidly. It swept away the notion of consensus and partnership between central and local government that had underpinned the education service since the Balfour Act of 1902…" (Donnelly and Jenkins 2001, p102)*

Viewing the reform in England and Wales from a more positive stance, the political aim was to increase the accountability of teachers to provide better quality science education. Since the educational authority legitimizes the curriculum, the reform also holds the government accountable for raising standards, a recurrent theme emphasized by the curriculum developers (DfEE/QCA, 1999, foreword). Frost (1999) describes the situation succinctly.

> *"The [first] revision of the National Curriculum in Science (May 1989), which became the first order for the National Curriculum in science, had incorporated all requests of the Secretaries of State, which paved the way for the dominance of assessment and accountability over curriculum." (p.165)*

To ensure that change will occur in the desired direction, appropriate machinery was already in place. The School Curriculum Assessment Authority is charged with the responsibility for overseeing the implementation and assessment of the National Curriculum, and the Office for Standards in Education (OfSTED) for administering the school inspection programme (Davis 1997).

The stepping up of governmental control over the science curriculum is not unique to the UK. A similar change, though on a smaller scale, had occurred in Norway as reported by

Brekke, Kjaernsli and Lie (1997). Since 1987, science in primary schools was taught as part of a civics course, the O-fag, which placed a strong emphasis on environmental issues, and schools and teachers could teach topics of local interest. However, beginning in 1997, O-fag was split into two separate subjects, natural and social sciences. There was also a stricter control of the content taught in natural sciences, with requirements specified for each year, instead of for three-year periods. This change was seemingly due to the fact that many primary teachers tended to avoid science topics and focused on the social sciences. The reform has apparently resulted in less freedom in schools in the way teachers plan and deliver the curriculum to ensure adequate coverage of science content.

Despite the unease created by centralizing curriculum development in some parts of the western world, this power-coercive mode of curriculum development is common in many other places in the Far East like China, Hong Kong, Singapore and Japan. The Chinese system was an extreme example of centralization, which used to mandate a national curriculum and permit only the state publisher to publish textbooks for use throughout the country. However, recently signs of loosening of this rigid control are apparent. The education authority has decided to give autonomy to the provinces to design their own curricula and publish textbooks as long as their curricula follow a set of national standards. This new policy is contained in the official document entitled "Guide to curriculum reform in basic education" (Ministry of Education, the People's Republic of China 2001). Its rationale is to adapt the curriculum to meet the diverse needs of individual provinces although the extent to which the new system will change the present scenario remains to be seen.

A parallel movement occurred in Israel where the relevance of science to the lives of students is viewed as a major issue. Israeli science education shifted toward school-based development of curriculum and materials. Tamir (1997) reports that curriculum specialists in

Israel are changing their role from designing inflexible programmes to visiting schools and assisting in the development of school-based materials.

No matter which direction these countries are taking with regard to curriculum control, the common theme is to increase accountability on the part of curriculum deliverers. Some countries achieve this by stepping up central control on the premise that a statutory curriculum coupled with an elaborate system of monitoring and assessment will make schools and teachers more accountable for their own teaching. Others are taking an opposite direction by decentralizing state control to increase accountability at provincial or school levels to develop curricula that best serve local needs.

2.3.3 The economic context

As argued by Fensham (1992), society needs a limited but definite number of persons with scientific skills and expertise to maintain and expand a society's economy. This desire for science curriculum to serve economic ends has become more obvious in the light of increased applications of science in technology and industries. This is evident in both the developed and developing parts of the world. In the USA, the need for reforming the science curriculum in the 1980s was linked to its perceived economic decline in relation to other countries, especially Japan (AAAS, 1990). The American Academy for the Advancement of Science (AAAS) concluded from the US education reports of the 1980s that

> *...in our postindustrial society, there is a strong connection between how well a nation can perform and the existence of high quality, widely distributed education. There is now a clear national consensus in the United States that all elementary and secondary school children need to become better educated in science, mathematics, and technology. (AAAS 1990, p210)*

The intention to foster economic development through science education is expressed perhaps most explicitly by Singapore. Chan, Chang and Toh (1997) from the Singapore Ministry of Education maintains

> *"One of the concerns in the science curriculum is encouraging more pupils to embark on science and engineering courses at the tertiary level. With a greater pool of scientists and engineers, the country can move to the next phase of its development, including research and development, innovation, and design in high value-added and high-tech industries." (Chan, Chang et al. 1997, p.335)*

By contrast, the National Curriculum in the England and Wales (DfEE/QCA, 1999) has set a more subtle aim, emphasizing that science learning should contribute to the development of enterprise and entrepreunial skills "through pupils learning about the work of scientists and of the ways in which scientific ideas are used in technological products and processes" (p.9).

Instead of aiming to gain a competitive edge as in those developed countries, many developing countries view science curriculum reforms as a means to achieve national self-reliance. This is conceivable in the light of the historical background of these countries as dependent territories of western colonial powers, and their relatively underdeveloped economy and industry. For instance, in Botswana, reform took place in the belief that it would enhance national self-reliance through elevating the country's scientific and technological capabilities (Prophet 1990). In Nigeria, the science curriculum developed in 1985 was designed to enable students to acquire laboratory techniques and conceptual thinking skills considered necessary for scientific self-reliance (Adamu 1989).

To this zeal of reform for achieving national economic progress, Drori (1998) sounds a note of caution. He argues that the causal link between science instruction and national progress is empirically problematic and has not been proven. Benavot (1992) also argues that "the economic effect of science education may have more to do with 'hidden' cultural rules, orientations, and worldviews being transmitted than the specific scientific content being taught." It appears that the relationship between economic progress and simple adoption of western science curricula is not a straightforward one as it first appears. This implies that relying merely on importing western science curricula without simultaneous change in culture may not achieve the aim to the extent these curriculum reformers would envisage.

2.3.4 The personal and social context

Another widely acclaimed cause for science curriculum reform in this past few decades is to make science available and more relevant to learners. This notion was embodied in the curriculum reform movement starting from the 1970s, under the umbrella of "scientific literacy" and "science for all". Hurd, a pioneer for scientific literacy, conceived the notion of scientific literacy as "an understanding of science and its applications to our social experience" with the aim of fostering "the emergence of an enlightened citizentry, capable of using the intellectual resources of science to create a favourable environment that will promote the development of man as a human being."(Hurd 1958; Hurd 1970).

Two influences were important in leading to this reform movement. First, the movement towards compulsory schooling in an increasing number of countries put pressure on curriculum planners for making science curricula more "inclusive". As noted by Millar and Osborne (1998), "the 'comprehensivisation' of the British school structure in the mid 1960s already drew attention more forcibly to the needs of the majority". Hence, making the curriculum more relevant to students' everyday life is seen to be equally important as, if not more important than training of future scientists. Second, with the booming of science-related technologies and their implications for personal and social lives and the global environment, purely academic science knowledge and practical skills were considered inadequate in helping the young generation to meet the needs of their future lives, and to develop their commitment to protect the environment. This has led to changes in the curriculum to incorporate more personal and applied aspects of science.

Spearheaded by western countries, a wave of reform for the development of scientific literacy started in the 1970s, culminating in a number of projects such as "Science in Society" (Lewis 1981), and the SISCON (Science in a Social Context) (ASE 1983). This trend evolved further into the approach of STS (Science-Technology-Society). The nature of STS courses is essentially interdisciplinary and aims to explore "the interactions between science knowledge, technological application, and the social context which directs the endeavours and either benefits or suffers from the results" (Solomon 1991). STS is now embedded in the notion of scientific literacy. Klopfer (1991, p947) provides a more contemporary definition of scientific literacy. He considers that scientific literacy comprises five components: (a) a knowledge of significant science facts, concepts, principles, and theories; (b) an ability to apply relevant science knowledge in situations of everyday life; (c) the ability to utilize the processes of scientific inquiry; (d) an understanding of general ideas about the characteristics of science and about the important interactions of science, technology, and society; and (e) the possession of informed attitudes and interests related to science. These goals have persisted as an important driving force for curriculum reform towards the twentieth-first century, and becoming increasingly nationalized and globalized. I cite examples to explain how this happened in some parts of the world in the recent decade.

In the USA, scientific literacy is treated as the main theme of the two major initiatives for setting national standards in the 1990s. One set of standards was designed by the American Association for the Advancement of Science (AAAS), and the other by the National Research Council (NRC).

The NRC published the *National Science Education Standards* (NRC 1998), defining four goals for school science, which are considered important attributes of a scientifically literate person:

- *Experience the richness and excitement of knowing about and understanding the natural world;*
- *Use appropriate scientific processes and principles in making personal decisions;*
- *Engage intelligently in public discourse and debate about matters of scientific and technological concern; and*
- *Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers." (NRC 1998 p.13)*

To realize these goals, the *Standards* proposes changes in curriculum content, with more emphasis placed on "learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science", rather than "studying subject matter disciplines for their own sake." (NRC 1998, p.113). Along similar lines, the *Benchmarks for Scientific Literacy* published by the AAAS (1993) also specifies how students should progress toward science literacy by recommending what students should know and be able to do by the time they reach certain grade levels. Hence, unlike the earlier scientific literacy movement in the 1970s, which took place haphazardly, the emphasis of scientific literacy is now regarded as a national priority in science education.

Across the Atlantic, in England and Wales, Science in the National Curriculum also contributes to the understanding of the relationship between science, technology and society. In the section 'Importance of Science', the curriculum document states,

"...Through science, pupils understand how major scientific ideas contribute to technological change – impacting on industry, business and medicine and improving quality of life. Pupils recognize the cultural significance of science and trace its

worldwide development. They learn to question and discuss science-based issues that may affect their own lives, the direction of society and the future of the world."
(DfEE/QCA 1999, p15)

Hence, discussion on the applications of science and technological developments and their benefits and drawbacks is encouraged.

In Scotland, science reform is encompassed in a whole curriculum reform known as the 5-14 Development Program (Harlen 1995). Science is studied as one of the five components of a composite subject known as Environmental Studies, together with social subjects, technology, health education, and information technology. This arrangement indicates a strong inclination to strengthen the linkage between science and technology in the social and environmental context.

A contextualized and socially related science curriculum is also evident in the new science programme in Spanish schools, which extends its goals to cover not only STS-related knowledge, but also relevant skills, attitudes and behaviours. Among the nine objectives of the curriculum, four deal explicitly with the relationship between science and society, including the production of 'personal and reasoned criteria on scientific and technological issues', and using 'knowledge about human body for developing and affirming habits of body care and health' (Jimenez-Aleixandre and Puig 1995).

In Asia, many countries have also responded to this personal and social context of curriculum reform. In Malaysia the latest reform places emphasis on social values to make students more responsible for the use of natural resources, appreciate the beauty of the natural environment, and preserve its cleanliness for healthy living (Lee, 1992). In Singapore, apart from its clear economic goals, the secondary science programme also aims at promoting "a critical awareness of the interaction between science, technology, and society", and developing "an awareness and understanding of the environment", creating "positive attitudes and behaviours toward its use" (Chan, Chang and Toh 1997, p. 335). In Korea, the objectives specified by the new science curriculum for high schools are concerned with fostering an understanding of the relationship between science, technology and society (Han 1995).

The development in China follows similar trends. The new *National Science Standards* considers that science should fulfill the needs of both students and society. The following statement spells out a basic conception in designing the primary science curriculum:-

> *"The curriculum content should be related to children's everyday lives and tie in with the modern trends of scientific and technological developments. It should be adapted to the needs of societal development and should form the basis for children to build their own knowledge throughout their lifetimes."*
> (Ministry of Education, the People's Republic of China 2001, p.2)

In sum, there is a considerable degree of convergence of national curricula in placing science learning in a social context. Science reforms are expected to reflect the impacts of science on society. These include how science serves society through technological applications, what impacts these applications may bring to mankind, to society and our environment, and how students can help reduce negative impacts to a minimum through making informed personal decisions.

2.3.5 The educational context

Despite the importance of political, economic and social goals in spurring science curriculum reforms, reforms necessarily took place in an educational context. There has been an increasing need to underpin the choices of content emphases and teaching approaches by sound educational theories and pedagogy in order to achieve the goals of reform. These important underpinnings in the educational context will be discussed in the following sections.

The role of science process

It has long been recognized that science represents not only a body of knowledge, but also processes through which scientific knowledge develops. Schwab (1962, p203, cited in Tamir, 1991, p899-900) differentiates the *substantive* which consists of a body of concepts from the *syntactic,* i.e. the processes, which involves "the pattern of its procedure, its method, how it goes about using its conceptions to attain its goals". These processes of science are perceived as comprising cognitive or mental skills generally taken to include observation, interpretation, formulation of hypotheses, the planning for systematic investigations, and the drawing of conclusions (Harlen 1991). While the status of science concepts in the curriculum remains more or less stable, the place of science processes and how they should be taught appear to be more fluid.

Back in the 1950/60s, stage-managed heurism or the guided discovery approach was advocated as a means for teaching science processes. This kind of approach characterized many of the early science curriculum reforms at that time including the Nuffield Science Teaching Projects. In the 1970s, the guided discovery approach was further popularized by the development of programmes like Scottish Integrated Science which was widely adopted in overseas including Hong Kong. However, with the passage of time, the use of science processes for the rediscovery of well-documented concepts has come under increasing criticism (Woolnough 1991; Hodson 1993). The major criticisms are that this kind of approach lacks resemblance to the genuine work of a scientist, nor is it particularly effective for the learning of concepts when compared with other methods. These criticisms paved the way for projects like the *Warwick Process Science* and *Science in Process* developed in the

1980s, which emphasizes the development of science processes for their own sake (Screen 1986). However, this complete swing from content- to process-based approach has been criticized on the ground that science processes cannot be separated from content and context, which give meaning to them (Millar and Driver 1987). This may explain why these curriculum projects did not appear to achieve a significant impact in their times.

Recent research evidence has shown that although students are capable of conducting investigations and collecting data, they have very little understanding of the meaning of the data (Foulds, 1992 cited in Gott, 1998). The study by Millar, Lubben et al (1994) in the Procedural and Conceptual Knowledge in Science (PACKS) Project reveals that children's understanding of the aims and purposes of investigating in science, and the ideas underpinning the criteria for evaluating the quality of empirical data are important factors in determining children's performance in an investigation task. Studies by Gott and Duggan (1998) investigated the meaning of evidence and the importance of understanding concepts of evidence in increasing the reliability and validity of an investigation.

As noted by Donnelly and Jenkins (2001, p71), the work of Gott was influential in the revision of the attainment target concerning science investigation in the National Curriculum in England and Wales. This is evidenced in the change of emphasis from the first version of the curriculum which was based mainly on traditional science processes (DES/WO 1989) to the third version that incorporated three areas: 'Planning experimental work', 'Obtaining evidence' and 'Considering evidence' (DFE/WO 1995). The latest version of the National Curriculum includes 'Ideas and evidence in science' in addition to 'Investigative skills' (DfEE/QCA 1999). This emphasis on evidence is made explicit in the level descriptions under *Attainment target 1: Scientific enquiry*, where science method is seen as about "developing and evaluating explanations through experimental evidence and modeling"

(DfEE/WO 1999, p.15) rather than merely as a set or sequence of process skills to be acquired. This development exemplifies how curriculum reform is informed by an increased understanding of the nature of learning science.

Concurring with the development in the UK, the *National Science Education Standards* of the USA also argue for a change in emphasis on inquiry, which is indicated as follows (NRC 1998, p.113):

Less emphasis on	*More emphasis on*
Getting an answer	*Using evidence and strategies for developing or revising an explanation*
Science as exploration and experiment	*Science as argument and explanation*
Providing answers to questions about science content	*Communicating science explanations*
Concluding inquiries with the result of the experiment	*Applying the results of experiments to scientific arguments and explanations*
Emphasis on individual process skills such as observation or inference	*Using multiple process skills – manipulation, cognitive, procedural*

Interestingly, the changes in emphasis were drawn to a great extent from Schwab (1960), whose ideas were also influential in the 1960s. Schwab's ideas on science inquiry are cited extensively in the *Teachers' Guide* accompanying the *National Science Education Standards* (NRC 2000). He suggests four possible approaches in conducting inquiries:-

1. *Laboratory manuals or textbook materials could be used to pose questions and describe methods to investigate the questions, thus allowing students to discover relationships they do not already know.*
2. *Instructional materials could be used to pose questions, but the methods and answers could be left open for students to determine on their own.*
3. *Students could confront phenomena without textbook- or laboratory-based questions. Students could ask questions, gather evidence, and propose scientific explanations based on their own investigations.*
4. *Teachers provide students with readings and reports about scientific research. They discuss the details of the research: the problems, data, role of technology, interpretations of data, and conclusions reached by the scientists. Where possible,*

students read about alternative explanations, different and perhaps conflicting experiments, debates about assumptions underlying the research and the use of evidence, and other issues of scientific inquiry. Through this approach, students build an understanding of what constitutes scientific knowledge and how scientific knowledge is produced. (Schwab referred this to as "enquiry into enquiry.")
(NRC, 2000, p.16-17)

The second, third and fourth approaches exert a strong impact on the writing of the *Standards*. Apart from Schwab, the *Teachers' Guide* also refers to the ideas of Millar and Driver (1987) that "cognitive abilities" required for conducting inquiry should go beyond science process skills. This leads to the advocacy that "inquiry abilities require students to mesh these processes with scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science" (NRC 2000, p.18). The *Teachers' Guide* regards five features as essential for classroom enquiry:

- *Learners are engaged by scientifically oriented questions.*
- *Learners give priority to* ***evidence****, which allows them to develop and evaluate explanations that address scientifically oriented questions.*
- *Learners formulate* ***explanations*** *from evidence to address scientifically oriented questions.*
- *Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.*
- *Learners communicate and justify their proposed explanations.*

(NRC 2000, p.25)

Parallel to the new emphasis on "science processes" is a related trend in recent curriculum reforms, which is to increase the use of full and genuine investigations in developing science processes in students. Watson and Wood-Robinson (1998) characterizes investigations as activities in which students have to make their own decisions and they are given some autonomy in the planning process. They would also involve students in using procedures such as planning, measuring, observing, analyzing data and evaluating methods.

Woolnough and Allsop (1985) claim that investigations enhance the development of knowledge and provide students with tools of thought. It could also develop in students the habits of working like a problem-solving scientists, and to enable them to gain a wide range of tacit knowledge, and confidence in using it. There has been a conscious attempt to differentiate investigation from traditional practical work by treating it as a more in-depth way to develop knowledge and find out answers to scientific questions. For example, Jenkins (2000) argues that investigation should encourage the development of new knowledge and understanding for a particular purpose and within a context of action rather than reconstructing existing knowledge. Hodson (1998, p.96) went further to describe investigation as "holistic, fluid, reflexive, context-dependent and idiosyncratic, not a matter of following a set of rules that requires particular behaviours at particular times". He also advocates a shift from "student as technician" who knows only to carry out teachers' instructions to "student as creative scientist" with sole responsibility for the inquiry (p.99). This he sees as instrumental in developing ownership of the inquiry that provides stimulus for extending their conceptual and procedural knowledge.

In line with these, the *National Science Education Standards* advocates changes in emphases of practical activities, which are outlined as follows (NRC 1998, p.113):-

Less emphasis on	*More emphasis on*
Activities that demonstrate and verify science	*Activities that investigate and analyse science questions*
Investigations confined to one class period	*Investigations over extended periods of time*
Process skills out of context	*Process skills in context*
Doing few investigations in order to leave time to cover large amounts of content	*Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content*
Private communication of student ideas and conclusions to teacher	*Public communication of student ideas and work to classmates*

The idea of the role of complete investigations is reflected elegantly in the science curriculum of New Zealand, which views scientific investigations as involving "an interaction of many complex skills, including focusing, planning, information gathering, processing, interpreting, and reporting". When compared with the American *National Science Education Standards,* the New Zealand's curriculum describes investigation even more broadly. It states,

> *"Students may be investigating by carrying out a practical investigation of the "real world", by carrying out an investigation of appropriate reference material, or by integrating these approaches." (New Zealand Ministry of Education 1993, p.43)*

The curriculum document suggests many practical activities that allow students to carry out investigations using these three approaches. For example (The headings are added by the author for clarity sake):

Investigating the "real world":

- *Conducting a "fair test" into the flammability of a range of materials;*
- *Building a waka, from harakeke, which will hold 500 grams;*

Investigating appropriate reference materials:

- *Reading a range of journals and newspaper articles when beginning a study on the effects of biotechnological developments on medical treatments of genetic diseases*
- *Asking adults about changes in their town*

Integrating "investigating appropriate reference materials" and "investigating the 'real world'":

- *Deciding what information is required to make appropriate planning decisions for an investigation into insect life cycle;*
- *Using the local council library to obtain information to prepare for a project on shellfish gathering at the local beach.*

(New Zealand Ministry of Education 1993, p.48-50)

Although the curriculum connects investigations to specific content areas in order to set the context, these activities are not intended for eliciting basic or well-documented concepts characteristic of the guided discovery approach prevalent in the 1970s. Instead, investigations are used to provide "key opportunities for students to extend their understanding in science", and to "develop the scientific skills and attitudes required to enhance their ability to explore phenomena and events and to solve problems" (New Zealand Ministry of Education 1993, p.42).

In England and Wales, the National Curriculum regards open-ended investigative work as a key feature evidenced by the eight level descriptions specified under the Attainment Target 1. Starting from Level 2, i.e. at lower primary level, students are expected to make their own suggestions, with help, in collecting data to answer questions. And, at Level 4, students conduct a complete investigation by themselves. The detailed requirement for that level description is:

> *'In their own investigative work, they decide on an appropriate approach [for example, using a fair test] to answer a question. Where appropriate, they describe, or show in the way they perform their task, how to vary one factor while keeping others the same. Where appropriate, they make predictions. .... They select suitable equipment and make a series of observations and measurements that are adequate for the task.... "*

As students move from primary to secondary, they are expected to become increasingly independent in carrying out investigations, be able to evaluate their work and suggest how their working methods could be improved with justifications. Investigations is thus seen as a vehicle for students to plan and evaluate their own investigations "in relation to the strengths of the evidence they and others have collected" (DfEE/QCA 1999, p.28).

In sum, a more open-ended inquiry approach emphasizing evidence and argumentation for finding out answers to genuine problems seems to emerge as a current trend in teaching the 'process' element of science.

Psychological ideas in teaching and learning science

Curriculum reforms have also been influenced by psychological ideas as they are concerned with what and how children should learn in science. Science curricula have drawn on our understanding of children's cognitive development and the process of learning as contributed by scholars like Piaget, Bruner and Gagne, and more recently by the theory of contructivism.

The stage theory of Piaget maintains that cognitive development in children takes place through progressive stages, with cognitive structures and thoughts slowly developing eventually to a stage where they are able to think and hypothesize in abstract terms. Piaget's theory has not been extensively applied to science curricula. According to Lawton (1978), its influence is more on discouraging teachers to include something in the curriculum at too early a stage in children's development rather than on encouraging them to introduce curriculum contents at the most appropriate stage. Nevertheless, some curriculum projects in the 1970s were structured on the basis of Piagetian stages, for example, the Science 5/13 and Australian Science Education Project. They sought to match curricular aims with students' cognitive levels, though they were not particularly welcomed by teachers (Lawton, 1978). Lawton postulated that this might be due to the lack of interest in psychological ideas among teachers, and the large class sizes which made small group teaching very difficult.

A more recent attempt to apply Piagetian stages in the curriculum is the *Cognitive Acceleration through Science Education Project* (CASE) (Adey 1998). This comprises interventions into children's ability to process information and to accelerate students' cognitive development . The project has produced a set of teaching activities entitled *Thinking Science*, which claims to achieve considerable successes in producing "value-added effects" by elevating students' levels of attainment. Apart from Piagetian theories, *Thinking Science* also draws reference from Vygotsky's ideas that instruction should proceed ahead of the cognitive development of children to facilitate the process of cognitive maturation (Adey, Shayer et al. 2001).

Apart from Piaget and Vygotsky, Gagne and Bruner also left their marks in a number of projects. Gagne's views that learning of simple ideas is a prerequisite for learning of complex ones were influential in the Schools Council Integrated Science Project and other Americans elementary and junior high school projects. The way that SCISP was organized was based on the kind of learning hierarchy promoted by Gagne (1970). Bruner's ideas of discovery learning and the readiness to learn were espoused by a number of senior secondary projects (Fensham, 1992). Bruner's notion of spiral curriculum was particularly influential in the development of the old primary science curriculum of Hong Kong (HKCDC 1980).

More recent science curriculum reforms in the recent decade have been influenced by the constructivist approach to learning. This approach, synthesized from researchers' findings about how children construct their understanding of science (Driver, Squires et al. 1994), has enlightened curriculum projects as to the teaching approaches used for constructing or reconstructing students' conceptions of scientific phenomena.

Some of the national curricula or curriculum frameworks introduced in the 1990s incorporated the constructivist view in their design, notably the National Science Education Standards of the USA (NRC 1998) and the Science in the New Zealand Curriculum (New Zealand Ministry of Education 1993). One of the assumptions inherent in the formulation of the US National Standards is that "student understanding is actively constructed through individual and social processes" (NRC 1998, p.128). In the New Zealand science curriculum, one aim is "to advance learning in science by portraying science as both a process and a set of ideas which have been constructed by people to explain everyday and unfamiliar phenomena." (p.9). As Bell, Jones et al (1995) argue, the use of "making sense of the world" as the key phrase in each of the learning strands is indicative of the constructive approach. Despite these influences, it seems wrong to see psychological ideas as forming a significant factor in driving curriculum reforms. Their service is mainly to enrich our understanding of the dynamics behind the learning of science and teaching strategies for learning to occur.

Educational assessment

Both national and international assessment studies have played a role in driving reforms. Perhaps, the most widely documented national assessment is the work of the Assessment Performance Unit (APU) of the UK which monitored the performance of UK students on science processes. Jennings (1995) argues that the APU provided much raw material for further work on ways in which children construct their scientific ideas. It had also driven further work concerning pupils' capacity to carry out complete investigations as well as providing a background in the enactment of the first national curriculum in England and Wales. Donnelly and Jenkins (2001) echo that the APU helped to "sustain and operationalize the notion of process in the science curriculum" and was "critically influential in the treatment of laboratory work within the National Curriculum for science" (p.79)

In Section 2.3.2, I demonstrated the importance of the political context for science curriculum reform in England and Wales leading to the enactment of Science in the National Curriculum. This political influence on changing the curriculum was exerted through institutionalizing a new framework for assessment. Prior to the enactment of the first version of the National Curriculum in Science, the Task Group on Assessment and Testing (TGAT

1988) published a report emphasizing assessment and testing as an important means to support learning. Paul Black, TGAT Chairman, describes the influence the report had on the National Curriculum.

> *It made immediate demands on the form of the curriculum specifications, it specified novel demands for the coming SATs and it looked for substantial developments in teachers' formative assessment. (Black 1995, p.166)*

Results of international assessment exerted an equally strong influence in driving reforms. The IEA conducted two influential large-scale international studies since the 1980s: the SISS in the 1980s and the TIMSS in the 1990s. Results had attracted wide publicity and were taken into account to varying degrees in evaluating national curricula. In Korea, the development of the sixth national curriculum took into consideration the poor performance of Korean secondary school students in SISS. As a result, the content was reduced to allow more room for the development of science process skills (Han 1995). The findings that Japanese students did poorly on science items with relevance to everyday life led to inclusion of practical subjects in the national curriculum (Watanabe 1992). The same thing happened in the USA. The AAAS (1990) concedes that recent reforms were partly a response to public concerns about the low test scores of science students and their being ranked near the bottom in international studies.

The results of international comparison acted the other way round in England and Wales. The improved performance of English students in science was taken as an indicator of the effectiveness of the national curriculum in enhancing standards, notably in the area of practical science (Millar and Osborne 1998), and particularly as a reflection of the strong emphasis on investigations (Watson and Wood-Robinson 1998). These examples exemplify the utility of assessment outcomes either to justify demands for reforms or to legitimize past reform efforts.

2.3.6 Reflections on the context of reforms

The context and driving forces for reforms are complex and often interwoven. It was rare for any single reform to be driven by a single force. Political and economic interests appear intertwined. The demarcation between economic and social context are indistinct. This is because as science and technology have permeated almost every aspect of society and human life, a scientific literate citizenry would definitely enhance the nation's economic gain through increasing production and through protection of the environment.

The educational driving forces for reform necessarily operate within other contexts since education does not exist in a social and political vacuum. This is evidenced in cases where educational ideas or theories have been used to pursue political, economic or social causes, and vice versa. For example, Jennings (1995) argues that the 'equality' emphasis of the 70s and 80s helped promote 'balanced science for all'. He further argues that this encouraged a change from normative assessment to graded assessment as suggested in the TGAT report, culminating in a pattern of criterion-referenced statements of attainment in the national curriculum. So in this case, educational, personal-social and political influences intertwined. A personal-social cause was achieved by both educational and political means.

I would argue that science curriculum reform might not be as rational as it seems to be. From the influences that western curricula such as Nuffield, Biological Science Curriculum Study (BSCS) and Scottish Integrated Science in the 1970s -1980s have on the rest of the world, reform looks more like jumping onto the bandwagon than a genuine response to indigenous needs. I cite the reform in Cyprus as an example.

As argued by Zembylas (2002), the history of curriculum reform in Cyprus was a reflection of foreign influences predominantly those from the USA and UK. Zembylas criticizes that curriculum reform in Cyprus in 1994 based on guided discovery was an uncritical adoption of overseas ideas that have already been abandoned even in the countries where this approach was originated. He criticizes the reform as a symbolic one, for Cyprus has never had sufficient resources to fully support the changes. Zembylas further argues against the strong tendency in Cyprus to promote "cosmopolitan science", the kind of science seemingly accepted universally as suitable for teaching in schools, to the exclusion of contents that are responsive to local needs.

The case of Cyprus and other countries as discussed previously reflects that curriculum reform is a complex decision making process. Ideally it should take into account different contexts in which the reform occurs, balancing different stakeholders' needs. In reality this is often not the case. As distilled from the previous review of the context of reforms, I would argue that the reformers' perception of contextual information available to them and their assumptions about the causal effects of alternative decisions are important in determining the direction of the reform. This kind of information is multi-dimensional and multi-faceted, bearing upon the political, economic, personal-social and educational context. With the rapid flow of information, curriculum reform has become a globalized affair, implying that reform in western countries will exert an even greater impact on other parts of the world. This is a mixed blessing. On one hand, the developing world is now better informed of the new developments in countries staying in the forefront of science education. However, on the other hand, many of the theories or practical information that underpinned reforms in western countries may not have been well tested in different classroom situations or cultural contexts. Hence, the uncritical adoption of these ideas may be to the disadvantage of the developing countries which generally lack strong research enterprise for curriculum evaluation. Evidence for this will be provided in the next Chapter.

After maintaining a status quo for about two decades, Hong Kong is poised to improve its science education provision. As discussed previously, curriculum development in Hong Kong was under strong political influences because of its colonial status. With the transition of Hong Kong to the post-colonial era, and with the change in the context of science education worldwide, the curriculum decision-making process is likely to be more complicated than previously. The review in this section strongly implies that the curriculum planners' assumptions about (1) the context of reform, (2) the needs of Hong Kong students, and (3) the best strategies to fulfill those needs, are likely to influence the direction of the present reform. These will be explored in this study to gain a complete understanding of the present reform process.

In the following section, I turn my review to examine the factors influencing successes and failures of reforms. This is useful because given the context for reforms and the reformers' expectations, it is worthy to examine what lessons were learnt from previous changes in terms of what determines success or failure. I focus mainly on critical issues and problematic areas of past reforms, which should help to shed light on the foci of inquiry for the present study.

2.4 Factors determining the success and failure of reforms

The rhetoric of reform is one thing, but having it implemented to achieve the expected outcomes is another. From literature, the factors that determine success or failures of reforms are complex. I focus my discussion on two levels: the intended curriculum and the implemented curriculum. However, these two levels should be treated as interrelated since the implemented curriculum would undoubtedly be affected by the intended curriculum. This is because problems arising in implementation may reflect non-compliance by teachers as well as intrinsic weaknesses of the intended curriculum.

2.4.1 The intended curriculum

Fullan and Stielgelbauer (1991) identify four characteristics of curriculum change that can affect implementation, namely need, clarity, complexity, and quality and practicability. These four characteristics can be translated into four questions: (1) Do teachers perceive the needs for change as important as the curriculum planners do? (2) Are the essential features of the change made clear enough to teachers? (3) Is the change difficult and involve significant alterations in beliefs, teaching strategies, etc.? and (4) Is the change of good quality and practicable? This framework is useful for analyzing the factors determining the success of previous science curriculum reforms as drawn from literature.

Need for change

Change only occurs if teachers perceive a need for the reform (Fullan 1993). The AAAS (1998) reported that despite the efforts and investment of resources and expertise in the 1950/60s in the USA, few changes occurred in the mid-1970s. Teaching was primarily didactic and many students were rarely engaged in inquiry, critical reasoning and problem solving. This was attributed to a lack of communication or link between scientists who were responsible for designing the curriculum, and the teachers. Teachers did not understand what "real" science was and hence failed to appreciate the needs for reform. Hence, later reforms tried to engage both teachers and scientists in the development process.

In reviewing science curriculum reform in Cyprus, Zembylas (2002) argues that simply borrowing foreign curricular ideas and presenting them in a contemporary packet does not mean convergence with international trends will occur. This is because teachers may not perceive a need to converge with international trends due to a lack of communication with the reformers. Moreover, local needs are not addressed by the mere adoption of other curricula. Even if the reformers' intentions are communicated to teachers, there may be different viewpoints between the two. Gallard and Gallager (1994) report a contradiction between reformers' and teachers' perceptions in an evaluation study on the new national science programme in Costa Rica. The new science programme was mandated by Costa Rica's highly centralized system of education, but was oriented towards the needs of university-bound students who constituted only about 4% of the age group. Science teachers' reactions to the new curriculum were negative, mainly because they thought that the reformer ignored their professional knowledge and required them to take up tasks that were inappropriate for the majority of students and virtually impossible to achieve. Thus, the researchers envisaged that the teachers would not adhere their practices faithfully to the reform.

Reform may also fail if corresponding assessment is not in place. The reason is that assessment creates an immediate need or concern for implementation of a curriculum, since it holds schools accountable to the public for their practices. The importance of assessment to curriculum reform was fully recognized by the AAAS in one of its publications for Project 2061, "Blueprints for reform". It acknowledges that assessments exert a very powerful influence on curriculum and instruction:-

> *"The higher the stakes associated with performance on the examination, the more it will influence the curriculum"* (AAAS 1998) *p.47.*

This led the AAAS to conclude that any effort in nationwide science education reform must include reform of student assessment as a major goal. Nevertheless, the AAAS concedes that despite the merits of assessment, some of the indirect results of high-stakes examinations, such as teaching to the test, and excessive focusing on skills and vocabulary are inconsistent with many of the aims of reform. The effects of the inclusion of practical assessment in the GCSE in the UK reflect this paradox. Donnelly, Buchan et al (1993) reported their findings about the implementation of the practical assessment of GCSE. They found out that although the notion of "skill" had dominated teachers' language when discussing practical assessment, teachers were too preoccupied with training their students to obtain the highest possible score that it was rare for them to engage students in reflections on the nature of scientific skills.

Clarity

According to Adamu (1989), the lack of clarity and precision in performance objectives may lead to interpretation problems. In an intrinsic analysis of the new science curriculum of Nigeria, the author found out that there was a long list of these objectives accompanied by a lack of clarity, precision and consistency in the words used to describe the performance behaviours. For instance, the leading verb, "identify" was used in different objectives to convey very different meanings and expectations from students, like "identify the sun as the ultimate source of energy", "identify dominant and recessive characters" and "identify chromosomes in permanently prepared slides of cells". This problem was aggravated by the use of a large number of verbs to describe many of the performance objectives when a few would be enough. Adamu (1989) cites the use of 21 leading verbs to describe a total of 102 stated performance objectives, which was considered excessive.

Complexity

There are situations in which the contents of the reform are difficult and necessitate great changes in belief. Ogawa (1998) argues that the view of science within Japanese culture is rather different from western views, making direct imposition of the western view problematic. For example, the author points out that Japanese students are not culturally prepared to draw cognitive conclusions from their observations. This is because the word "observe" is translated in Japanese as "kansatsu", meaning more than observation – the term also has an emotional aspect. Therefore, an object is not properly understood as an object by itself but is related to the observer. This may be premised on the lack of emphasis to make each man's understanding universal or logical since the thinking of most Japanese tends to be intuitive and emotional (Nakamura, 1964 p.575, cited in Ogawa, 1998). Prophet (1990) also argues that the traditional culture of Botswana, which emphasizes rote learning, and discourages innovative and critical attitudes, is incompatible with that of modern science. This culture has led to discrepancies between Botswana's new inquiry-based science curriculum and teachers' actual practices which remain didactic.

Another important issue that adds to this complexity and difficulty is the language or medium of instruction used for learning science. This is important because of the increasing number of science students speaking English as their second language. This problem is especially common in current or former British colonies, where English is still used as the classroom language. In such cases, students' progress in learning science hinges on the success in mastering the English language (Rollnick 1998). Prophet (1990) argues that the language barrier posed by English has prevented students from learning and communicating effectively in class. To resolve this, some countries use English at the start of primary school, e.g. in West Africa while others, such as Malaysia and Tanzania, opt for the local language instead of English. Even so, some indigenous languages are found to be deficient in expressing and learning science concepts, making translation of English terms into the local language difficult (Rollnick, 1998).

Quality and practicability

Reforms may fail because they are impracticable, particularly from the perspective of the teachers. Hacker and Rowe (1997) report that teachers in England and Wales have complained about experiencing trouble with an overloaded, but legally mandated curriculum. Teachers perceive too much content to be covered in a limited time, so teaching strategies that are perceived to be more efficient are preferred to more time-consuming ones. A similar situation is found in Japan, where experimentation has given way to didactic teaching at the secondary level because of excessive content (Miyake and Nagasaki 1997).

The National Curriculum in England and Wales has also raised problems of practicability with regard to its design. The 1991 version of the curriculum (DES/WO 1991) emphasizes integration of scientific exploration with the learning of concepts. In an evaluation study, many teachers commented that the content was not amenable to practical approaches. Teachers also reported that the way the levels of attainment were stated had obstructed efforts to interpret and implement appropriate classroom experiences (Russell, Qualter, et al, 1995). The evaluator suggested that it was necessary to identify good practices in the teaching of Science 1 ('Scientific Inquiry' which is the first of the four areas of study stipulated in the National Curriculum) and that more detailed specifications of the levels of attainment were needed to ensure progression. The evaluation study contributed to the redesigned National Curriculum issued in 1995 (DFE/WO 1995).

2.4.2 The implemented curriculum

The teacher

Researchers argue that reforms recur because they are never intended to transform schools and classrooms (Cuban 1992, Shymansky and Kyle 1992). Evidence abounds of curricula which were not implemented as intended (Vlaardingerbroek 1998). Van Driel (2001) suggests that teachers' practical knowledge, an integration of experiential knowledge, formal knowledge, and personal beliefs, has an important role to play in determining success or failure of a curriculum. He suggests that a greater chance of failure exists if teachers do not possess adequate knowledge of the new content or pedagogy to be implemented. There are several examples of this. In Korea, although integration of science topics is considered as important in the middle school curriculum, this has largely been ignored in the classrooms (Kim 1997) because of the different academic backgrounds of science teachers. In Norway, primary teachers tended to avoid science topics previously because of their lack of knowledge in science (Brekke, Kjaernsli and Lie 1997). Thirdly in the USA, when teachers were asked to teach science through an inquiry approach, they were unable to comply because most had learned science as facts to be memorized. This perception of science learning apparently did not change in their teacher training (AAAS 1998).

Schremer (1991) argues that the curriculum reformer should not assume that if a teacher fully understands the programme, he or she will necessarily adopt it. He identifies seven teacher variables that may affect teachers' likelihood of adoption. These are: (1) The teacher's skill in selecting and decision-making; (2) the teacher's proficiency in evaluating materials for the purpose of implementation; (3) preferential criteria teachers employ in the evaluation process; (4) the selective reading habits of the teacher; (5) the importance of values and vested interests in educational decision-making; (6) the teacher's willingness and openness to change; and (7) the teacher's self-image of his ability to change, bring about change in others and break old habits. Schremer goes on to argue that curriculum planners should be aware of these factors and whether their assumptions underlie the curriculum with regard to these factors.

Several researchers consider teacher change as a prerequisite for success in implementation of curriculum reforms. Tamir (1991) argues that teachers in new programmes are supposed to change their traditional role, for example, instead of serving as the source of knowledge, they are expected to teach science as inquiry by inquiry. Law (1994) also points out that teachers need to assume the role of facilitator rather than knowledge provider in implementing a model of learning through the STS approach. Hodson (1998) highlights the importance of bridging theory and practice in implementing reform in practical work. He maintains that even teachers who hold clear and coherent views about scientific inquiry do not plan practical activities consistently with their views, "concentrating instead on the immediate concerns of classroom management and on concept acquisition" (p.105). He argues that teachers need to work through both philosophical and pedagogical issues for themselves before real change will happen.

Hall and Loucks (1977) views teacher change as a gradual process. They devised a Concerns Based Adoption Model (CBAM) to describe how teachers experience a curriculum reform. According to the model, teachers will experience seven stages of concern in implementing a curriculum reform. At stage 0 (awareness), there is little concern or involvement in the reform. At Stage 1 (informational), there is a general awareness of the reform and the teacher is interested to know more about it. At Stage 2 (personal), the teacher is uncertain about the requirement of the reform and whether he or she can meet the demand. He or she is concerned about the conflicts with existing structures or personal commitment. Stage 3 (management) is the stage where the teacher will focus on implementation of the reform and how to manage the use of information and resources. At Stage 4 (consequences), the teacher is more concerned with student outcomes and the ways to improve them. When the teacher moves to Stage 5 (collaboration), the emphasis is on collaboration with others to make sure the reform can be carried out. At the final stage, Stage 6 (refocusing), the teacher is thinking about making improvement to the innovation and considering better alternatives.

The CBAM model sheds light on the implementation process from the perspective of teachers' adaptation to a new curriculum. It implies that teachers' concerns in implementing a new curriculum evolve with time, and hence the support provided to teachers should change accordingly.

Fullan and Stiegelbauer (1991) emphasizes the commitment of teachers to implement changes. He argues that some teachers, depending on their personality, previous experiences and stage of career, are more "self-actualized" and have a greater "sense of efficacy", which prompts them to make the effort required to bring about successful implementation. Research findings indicate that the teacher most willing to test new behaviours is one who feels teaching is rewarding and is satisfied with his/her job. Conversely, the dissatisfied teacher is not likely to change, except that this dissatisfaction is caused by external constraints that can be eliminated (Spector 1984) Fullan and Steigelbauer (1991) further argue that teachers' relationships with other colleagues is a critical variable. "Collegiality, open communication, trust, support and help, learning on the job, getting results, and job satisfaction and morale are closely interrelated" (p. 77). Their argument is in line with the CBAM Model, depicting collaboration among teachers as a more mature stage of concern to which teachers may progress in the reform process.

The above viewpoints concern whether teachers teach according to the intended curriculum. Snyder and Bolin et al (1992) argue that curriculum implementation should also be viewed from the "mutual adaptation" perspective, which recognizes that adjustments are made to the curriculum by both curriculum planners and teachers who actually use it in the classroom context. I would argue that both perspectives are important and should be taken into account for two main reasons. First, curriculum reform is a massive undertaking in response to changing needs of students and society, therefore adherence to the principles of the intended curriculum may have a greater chance for schools to move towards the desired goal. Second, it is unrealistic to expect teachers to adhere strictly to every detail and they should exercise professional judgment in adapting the curriculum to the particular context in which they teach.

Resources

Gross, Giacquinta and Remstein (1971) finds unavailability of required instructional materials often inhibits implementation. In the Philippines, for example, although the science curriculum at both primary and secondary levels is student-centred, it is handicapped by a lack of equipment and other resources, and a shortage of qualified science teachers (Ibe and Punzalan 1997). Even in developed countries teachers face many constraints. Many teachers in England and Wales suggested that financial constraints were an obstacle to the implementation of practical work as stressed in the National Curriculum (Hacker and Rowe 1997). The AAAS (1990) reports that in many schools in the USA, physical, administrative, and psychological circumstances militate against undertaking major curricular reform efforts. Teachers often lack time to think, organize materials and confer with colleagues. Many do not have private offices, computers for word processing, and laboratory assistants (p. 215)

School organization

Factors relating to school organization also affect the implementation of a reform. In Korea, most students cannot spend the necessary hours in the laboratory due to large class sizes coupled with a general shortage of laboratory equipment (Kim 1997). The AAAS also realizes that earlier reform initiatives in America failed partly because the rigidity of school organization such as self-contained classrooms, with desks in rows, and inflexible timetabling helped to perpetuate teacher-centred instructional practices (AAAS, 1998). Lee (1992) attributes the deviation of Malaysian science teachers from the Nuffield and Integrated

Science courses to social pressures to teach towards examinations.

2.4.3 Summary

From the above review of factors affecting the success of reforms, there are those that pertain to the intended or the implemented curriculum, or to both of them. At the level of intended curriculum, it is important for teachers to perceive the need for change before they would change their teaching accordingly. Underlying this is the requirement for a reform to meet the genuine needs of students or society for teachers to be convinced of it. There should be effective communication between the curriculum planners and the teachers. Appropriate assessment measures should be in place to ensure genuine implementation. The change needs to be spelt out clearly to avoid misinterpretation by teachers. It should not be too complex for teachers to comprehend or put into practice. It should be compatible with the school and social culture otherwise it will face opposition during the implementation process. Lastly the reform should be practicable and the objectives and requirements solidly grounded in classroom research.

At the implementation level, a whole range of teacher qualities are regarded important. These include teachers' practical knowledge, a full understanding of the change, the ability to adjust their own roles to the new needs, and teachers' commitment to implementing changes that are potentially beneficial to students. The ability for teachers to bridge theory and classroom practice by accommodating all sorts of constraints also contributes to effective implementation of the reform. This bridging process can be seen as a continuous adaptation of teachers to the reform through progressive stages. This review of the factors affecting curriculum reforms provides a sound basis for predicting the determinants of the success of the present reform. This implies a need for careful scrutiny of both the intended curriculum and teacher practices.

2.5 Junior secondary science curriculum reform in Hong Kong.

Having reviewed the context for previous curriculum reforms occurring elsewhere in the world and the determinants of success and failure of these efforts, I now turn back to Hong Kong to review the previous reform at the junior secondary level. This allows me to take stock of the situation prior to the present reform, thus enabling me to understand the driving forces behind it.

Before 1975, most Hong Kong secondary schools taught General Science in Secondary 1 to 2, and some taught Physics, Chemistry and Biology from Secondary 1. No matter which curriculum was adopted, the teaching approach was traditional and didactic. Experiments were performed only to verify scientific laws or principles, and a real enquiry approach was practised only by a handful of enthusiastic teachers (Liu 1974).

These traditional approaches were considered inappropriate, such that curriculum-planning officials recognized that a new approach was needed for students to acquire a real understanding of basic scientific concepts. In 1971, an inspector from the Her Majesty's Inspectorate (H.M.I.) from the UK visited Hong Kong to review science education at junior secondary level. In response, the General Science curriculum was abolished and replaced by the Scottish Integrated Science Project (SISP), as adoption of an existing curriculum was thought to be more efficient than creating a new curriculum from scratch (Liu 1974).

The reform was undoubtedly influenced by the colonial status of Hong Kong at that time. Liu thought that it was more efficient to adopt a curriculum proven successful in Britain and other Commonwealth countries following the British system (Liu, 1974). Hence, Hong Kong was jumping onto the bandwagon of her Commonwealth counterparts. SISP, also known as

"Science for the Seventies", was developed in Scotland in the 1970s. It originated from Curriculum Paper 7: Science for General Education (Scottish Education Department 1969, cited in Kellington and Mitchell 1978) which states the nature and philosophy of the course and the recommended teaching approaches. These are:

> 1. *A reduced emphasis should be placed on the retention of factual knowledge.*
> 2. *Pupils should be encouraged to gain experience of processes in science.*
> 3. *The discovery method should be used whenever possible.*
> 4. *Learning should be directed towards the achievement of specified objectives.*
> 5. *Pupils should be encouraged to achieve attitude objectives, particularly 'an interest and enjoyment in science', in addition to objectives concerned with knowledge, understanding and practical skills. (p.2)*

Against this background, a provisional syllabus for science was produced in 1975 (HKCDC 1975), following a two-year trial. According to the evaluation reports (HKED 1974; HKED 1976), the course was well received by teachers and pupils. SISP was originally intended for two academic years' study but was modified and expanded to cover three years to suit the Hong Kong education system. The CDC later published curriculum guides for Secondary 1 to 3 in 1979, 1982 and 1985 respectively, followed by a combined document in 1986. SISP was renamed Integrated Science (IS) and remained in place in Hong Kong secondary schools until 2000. The aims and objectives of the IS curriculum are provided in Appendix 2.1.

There was no official summative evaluation except for the two trial studies conducted before the full implementation of the IS curriculum (see Chapter 3). Yet, during its implementation, Hong Kong participated in the SISS and TIMSS, which provided a means for local educators to evaluate the IS curriculum. The salient findings of SISS are (Holbrook 1989; Holbrook 1990) :-

The intended curriculum:

- *The relevance of the curriculum to everyday issues is not so appropriate to Hong Kong students nowadays.*
- *There is no coverage on social and moral implications, of historical perspectives, of limitations of science, nor of the link between science and technology.*
- *Emphasis is mainly on the more traditional science skills of knowledge, understanding, application and manipulative ability.*

The implemented curriculum:

- *The teacher plays a central role in the teaching of science. "Chalk and talk" teaching still predominates and more than 70% of the students often or sometimes copy the teacher notes into their own books.*
- *There is little evidence that teachers regard problem solving or planning skills, and requiring students to show creativity and initiative, as important at any educational level in Hong Kong*
- *Worksheets are the main source of instructions and followed up most commonly by filling in blanks. Little time is given to compiling written records and hence writing up reports for homework is not a common activity.*

The achieved curriculum:

- *The results of the science tests are poor by international standards.*
- *Students have a very favourable attitude towards various aspects of science. Students think that science is very useful, important, relevant and an enjoyable school subject. Therefore students' poor performance is not due to unfavourable attitude.*
- *At the secondary 2 level, boys performed significantly better than girls, in particular, for physical science items.*

(The above findings are summarized from Holbrook (1989, p183-187) and Holbrook (1990, p81-110).)

Holbrook (1989) concluded the poor performance of Hong Kong students in SISS was attributable to the way science was taught in the classroom. He made the following succinct comments about how teaching practices led to poor students' outcomes.

With the group size sufficiently large that manipulative skills are not highly promoted, student involvement in many cognitive skills related to the experimental work is not *high and the guidance questions in the worksheets far from demanding in anything but ability to read English. (Holbrook, 1989, p.184)*

He further elaborated on the consequences of the approach and attributed these to the teachers and the textbooks.

...students are very dependent on the teacher and the teacher is not putting a high priority on independent thinking by students. Whilst the cognitive level is higher for students with high teacher involvement it was seen that overall achievement in Hong Kong are low and teaching approaches are probably one factor contributing to this (Holbrook 1990, p97).

According to Holbrook, teaching was geared too solidly to the textbook or experimental workbook and not enough attention was given to science as a human endeavour in which self-initiative, creativity and interest play important roles. It appears that the poor achievement at this level could be linked to uninspired teaching (Holbrook 1990, p.97). He criticized further that the curriculum as related more to teaching ideas of the 1960s put forward in many other countries than to the needs of Hong Kong students possessing more diverse aptitudes and abilities as a result of compulsory schooling.

The junior science curriculum remained unchanged in the period between SISS and TIMSS. One would expect that Hong Kong students' performance in TIMSS did not differ greatly from the results in SISS. This is confirmed by the results of the multiple choice and free-response items for Population 2 in TIMSS (Law 1996). The salient points are:

- *Hong Kong's performance is very close to the international average score, but is significantly lower than most of the other developed countries.*
- *The average performance of Hong Kong students is below or only comparable to the 25th percentile of Singapore, the best performing country, and only the top 5% of our students can match the performance of the top 25% of Singaporean students at*

Secondary 2.

- *Performance is better for the lower level performance expectations, but significantly poorer for items that test understanding of complex information, application of scientific principles to develop explanations, and the design of investigations.*
- *Students' performance are only marginally to slightly better for items in topic areas that have been taught in the school curriculum. Performance is particularly low for free response items.*
- *The improvement in performance from Secondary 1 to Secondary 2 is amongst the lowest in all the participating countries.*
- *Compared with the results obtained in SISS, Hong Kong is still among the lowest achieving groups of countries when compared with those that also participated in SISS.*
- *Hong Kong has the largest gender difference in science performance at grade 8 amongst the participating countries.*

(The above findings are summarized from Law (1996, p10-24).)

Given the above and the reforms elsewhere, there seems to be sufficient grounds for initiating a curriculum change in Hong Kong. The IS curriculum was considered outdated with little coverage of socially relevant topics. The teaching approach was traditional, didactic, uncreative and directed by highly structured worksheets. The achieved curriculum was unsatisfactory in comparison with other developed countries especially regarding the development of more complex understanding and process skills. Even the best students were not performing well enough. The gender difference remained wide if not widening.

In the light of the situation described above, a reform to the junior science curriculum is both justifiable and timely. The results of external assessment seem to provide a strong justification. In the last two decades, the Hong Kong science curriculum seemed unresponsive to the worldwide pressure for reforms, which called for the development of scientific literacy, and inquiry skills which lead students to a better understanding of the nature and processes of science. The unsatisfactory results of SISS and TIMSS suggest that both the intended curriculum and traditional teaching practices based on guided discovery are in need of change. Thus, an important criterion for evaluating the new curriculum reform is the extent to which the shortcomings of the previous curriculum could be overcome.

2.6 Summary

Previous science curriculum reforms could be considered in different contexts including political, economic, personal-social, and educational. Yet the exact influences that have driven change are distinct and unique to individual countries. As Black and Atkin (1996) point out, different countries attribute different weights to particular problems and that "no country is ever exactly in phase with any other because each is the creature of its own unique history and evolution" (p.12).

The same argument could also apply when considering the determinants of success and failure of reforms. This is because different countries are plagued by different problems to varying extents as a result of their unique political history, culture, financial resources and expertise in science education. A number of determinants can be distilled from the review. This includes factors pertaining to the quality of the intended curriculum, such as whether the needs for reform are recognized by teachers, whether the conceptualization and the content are clear, and whether the curriculum is too complex or impracticable. At the implementation level, the most important variables seem to be those pertaining to the teachers although successful implementation also depends on school organizational factors like class size and availability of resources.

In Hong Kong, the import of the SISP curriculum was influenced by the reformers' perceived advantage of direct adoption of a foreign curriculum. The choice of SISP of Britain was at least partly a political decision. Teaching was governed by the curriculum which set out details of all teaching activities and content. Textbooks and worksheets adhering closely to the official syllabus provided day-to-day support. The guided discovery approach governed, to a large extent, the way in which students learned. In actual implementation, this approach became even more teacher-led. The findings of the international studies indicated that the development of more complex processes and creativity were stifled, causing Hong Kong students to under-perform in these areas compared with counterparts in other developed countries. The curriculum was also plagued by a widened gender gap, and an under-achievement of the more able students.

Hence, reform in Hong Kong science curriculum was fully justified even based solely on educational consideration. Three themes can be drawn from the review in this chapter, and should be addressed in the present study. First, it is of utmost importance to understand what curriculum planners perceive as the driving forces of the reform, and the ways they consider most appropriate for achieving their goals. A second theme is whether the present reform is subject to the influences of those factors reviewed, and whether other factors are apparent. The third theme is whether the reform could help to overcome the weaknesses pertaining to different levels of the old curriculum as reflected by international studies.

In the next chapter, I will review literature on science curriculum evaluation and use the findings as a further basis for developing my evaluation framework and methodology of study.

Chapter 3: Science curriculum evaluation

3.1 Introduction

This chapter reviews key issues associated with curriculum evaluation. Its purpose is to inform the strategies and methodological design of the present study so as to make the present evaluation more effective. The first section defines curriculum evaluation and discusses the various models and methods for its implementation. By analyzing the strengths and limitations of these models and methods, useful references can be drawn in devising the framework for the present evaluation. The second section examines critically evaluation studies on science curricula conducted on an international or national basis. This could provide valuable information on the implementation of different evaluation strategies in different contexts. A matching of the methodology employed in these studies with their evaluation findings could tell whether these methods were effective or not. This part of review thus provides more concrete evidence of the viability of certain models in action.

3.2 Curriculum evaluation

3.2.1 Definition of curriculum evaluation

Tyler (1949) states that "the process of evaluation is essentially the process of determining to what extent the educational objectives are actually being realized by the program of curriculum and instruction". This defines evaluation as a process for assessing the worth of a program by comparing the outcomes against its stated objectives. Scriven (1967) criticizes this definition as overly restrictive. The Joint Committee on Standards for Educational Evaluation in the U.S. (1981, p.12, cited in Madaus and Kellagham 1992, p.120) provided a broader definition to cover the actual program itself: "the systematic investigation of the worth or merit of some object" including program, project, or materials. Cronbach (1983) provides an even more general view and considers curriculum evaluation as "the collection and use of information to make decisions about an educational program" (p.672), indicating that evaluation is a purposeful activity, feeding information back to stakeholders.

Curriculum evaluation can assume either a formative or a summative role. Formative evaluation occurs during the development of a curriculum. Its major purpose is to identify strengths and weaknesses of the intermediate versions of the curriculum, in order to obtain feedback for future revisions (Scriven 1967). On the other hand, summative evaluation is used to determine the merits of the curriculum in its final form. As researchers point out, the demarcation between formative and summative evaluations is never clear, because in reality many evaluators try to achieve both purposes by evaluating simultaneously a curriculum's merits and assessing possible improvements (Ahmann 1967; Morris 1996).

According to this understanding, curriculum evaluation should be considered as an integral part of curriculum reform. Cronbach (1983) put this message across succinctly:

> *"Evaluation is a fundamental part of curriculum development, not an appendage. Its job is to collect facts the course developer can and will use to do a better job and facts from which a deeper understanding of the educational process will emerge." (p.683)*

Shymansky and Kyle (1992) also emphasizes the importance of evaluation throughout the reform process. He wrote:

> *"Lessons learned in the reform process ought to be used both to modify the present reform process and facilitate future efforts in other locations." (p.760)*

In this thesis, I treat curriculum evaluation as a deliberate activity to investigate a curriculum including its program, implementation process and outcomes so that informed judgments can be made and improvements suggested. Since the present reform has already been implemented, the present evaluation study is by nature summative. Yet, it could still be used as a basis for improving classroom practice.

3.2.2. Models of curriculum evaluation

Based on the different conceptualizations about the focus and process of evaluation, a range of models has been developed by researchers to guide the evaluation process. I discuss each of these briefly.

Outcome evaluation

Outcome evaluation is concerned mainly with the evaluation of the achieved outcomes, that is, the "achieved" curriculum. It can be differentiated into two main types: goal-based and goal-free evaluations. Goal-based evaluations are to assess students' performance against some pre-determined criteria or goals. There are two approaches to this. The first approach is non-comparative evaluation, which seeks to assess students' performance against some pre-determined criteria in isolation from other curricula. So any conclusion drawn about the worth of the curriculum will be influenced by the subjective judgment of the evaluator. A second approach is to study the effects on students by comparing the differences between experimental groups and control groups using relevant criteria. This is called comparative evaluation. It is argued that comparative strategies are advantageous compared to non-comparative, because the former looks for differences to establish relative worth, while the latter necessitates devising an absolute scale (Scriven 1967).

Goal-free evaluation is not based on any pre-determined goals of the curriculum. It seeks to reflect the full range of reasonable outcomes of a curriculum without reference to its specific objectives (Scriven 1972). Scriven argues that goal-free evaluation safeguards against tunnel-vision effects implicit in goal-based evaluation. Such effects may arise from preoccupation of the evaluator with estimating the achievement of stated goals, at the risk of failing to observe strong unintended effects which may be more educationally desirable than the intended ones (West 1975). In goal-free evaluation, the evaluators bring additional goals judged from their professional expertise. In so doing, program-based bias will be eliminated and evaluators could get around purposefully overstated or purposefully understated goals of the curriculum planners. The result of the evaluation could then reflect a more complete picture of the outcomes of the curriculum, both intended and unintended. One difficulty with goal-free evaluation is that the criteria are made by the evaluator, so are therefore subjective. This can be resolved by matching learners' needs so that success can be judged by the degree to which these are met (Stecher 1991).

Intrinsic evaluation

In contrast with outcome evaluation, intrinsic evaluation emphasizes the intrinsic nature of the curriculum rather than its effects. This involves "evaluation of the content, goals, grading procedures, teacher attitude, etc." (Scriven, 1967, p 53). Intrinsic evaluation checks also internal coherence and consistency of the curriculum that cannot be evaluated empirically. This is important, as potential inconsistencies may create problems during implementation and lead to gaps between the intended and observed curricula and between intended and achieved curricula.

Eraut (1991) identified three possible roles for intrinsic evaluation in the development and evaluation of curriculum materials. First, independent analysis by an evaluator could help disclose developers' assumptions, foresee problems in field-testing, and make suggestions for improvements. Second, intrinsic analysis could form hypotheses to guide subsequent empirical investigation of outcomes, and predict possible patterns of use when combined with knowledge of common school practices. In this way, possible incongruence between intended and observed practice could be foreseen. Third, intrinsic evaluation may contribute to the final stage of a summative evaluation by highlighting the assumptions associated with the achieved outcomes, and illuminating these with the findings of content and consistency analyses.

Apart from the above conceptualizations of the nature of the evaluation process, there are more comprehensive models that incorporate the strategies and methods of an evaluation based on different research paradigms. Four prominent examples are reviewed: the Countenance Model, and the Context, Input, Process and Product (CIPP) Model, based on the positivistic paradigm; and the Illuminative Evaluation Model, and the Responsive Evaluation Model, based on the interpretive paradigm.

Stake's Countenance Model

Stake (1967) argues that curriculum evaluation must involve making judgments based on the data reported. Hence, he advocates the "Countenance" model which comprises a matrix incorporating both descriptive and judgmental data. The descriptive data includes intended and observed antecedents, transactions, and outcomes of the program. Antecedents are conditions that may influence the learning outcomes such as student aptitudes, previous academic performance, teachers' characteristics and other inputs to the programme. Transactions are encounters of students with teachers, student with student, and other kinds of interactions taking place in a school setting. Outcomes are products including students' academic achievement and other measurements of the impact of instructions. Stake argues that transactions are dynamic whereas antecedents and outcomes are static.

The analysis of data focuses on two aspects. First, the intended antecedents, transactions and outcomes are analysed to reveal the contingency among the variables in the three categories, that is, whether antecedents, transactions and outcomes are related. Second, the congruence between the intended and observed data will be recorded and judged on the basis of local or national standards. Figure 3.1 summarizes the process of data collection and analysis.

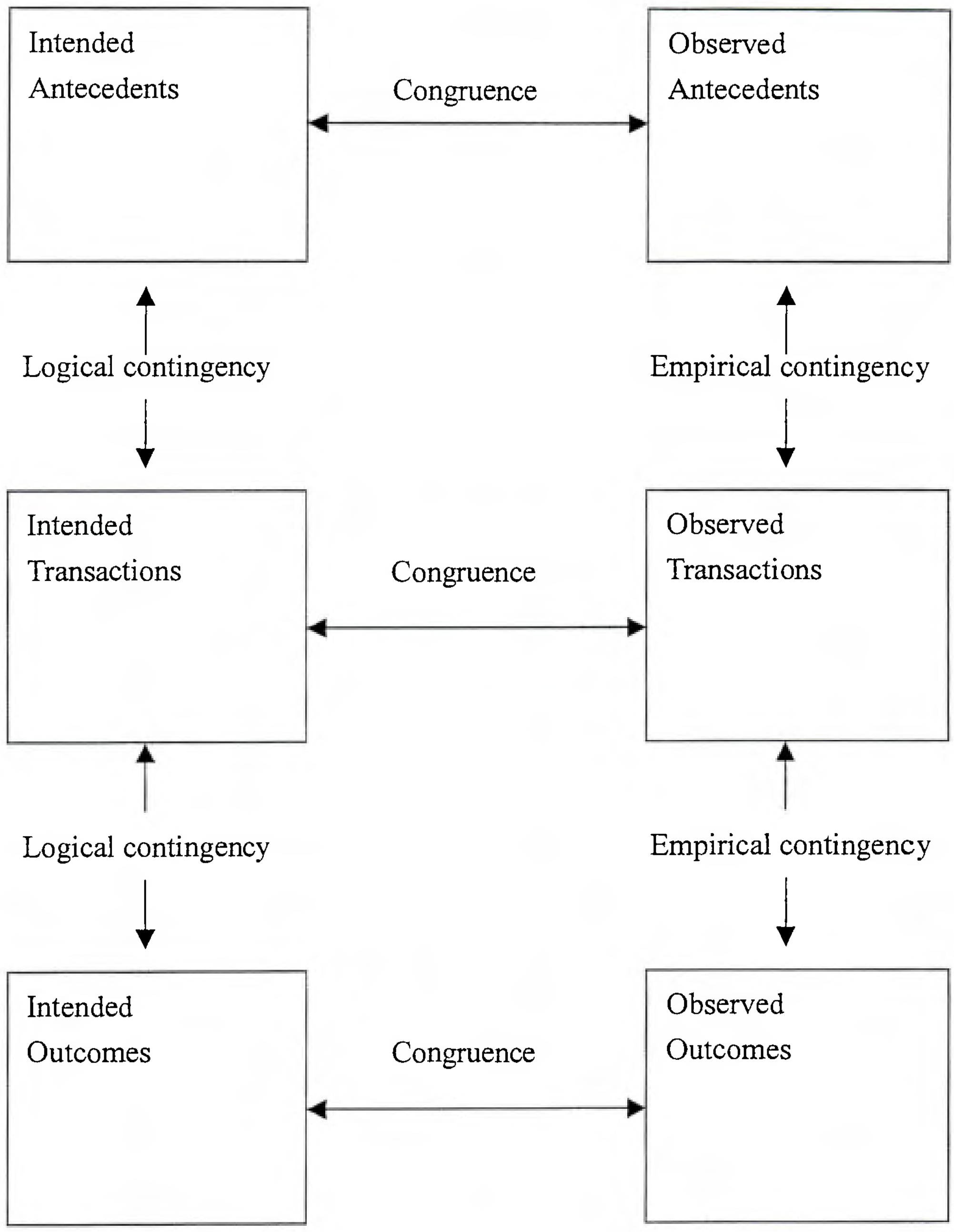

Fig. 3.1 A representation of the processing of descriptive data in Stake's Countenance Model (adopted from Stake 1967)

Stake's Countenance Model reflects a positivistic paradigm. It considers that curriculum outcomes can be measured objectively and that they are products of antecedents (or input) and transactions (or process). Embedded in the notion of contingency is that when the appropriate antecedents are present, there should be a greater chance to bring about the intended transaction, hence resulting in the expected outcomes. But even so, the observed antecedents, transactions and outcomes may not be congruent with the intended ones due to different factors affecting them. Therefore the evaluator should collect data on both the intended and observed curriculum, and make judgment on contingency and congruence.

Context, Input, Process and Product (CIPP) evaluation

The CIPP model is geared toward a systemic view of education. It was intended to provide ongoing evaluation services to the decision makers as an institution (Stufflebeam and Webster 1983). The name of CIPP model represents four consecutive evaluation processes, namely context, input, process and product. Details of the four parts are shown in Table 3.1.

	Context Evaluation	**Input** Evaluation	**Process** Evaluation	**Product** Evaluation
Objective	To define the institutional context, to identify the target population & assess their needs, to identify opportunities for addressing the needs, to diagnose problems underlying the needs, & to judge whether proposed objectives are sufficiently responsive to the assessed needs.	To identify & assess system capabilities, alternative program strategies, procedural designs for implementing strategies, budgets, & schedules.	To identify or predict, in process, defects in the procedural design or its implementation, to provide information for the pre-programmed decisions, and to record & judge procedural events & activities	To collect descriptions & judgments of outcomes & to relate them to objectives & to context, input, & process information; & to interpret their worth & merit.
Method	By using such methods as system analysis, survey, document review, hearings, interviews, diagnostic tests, & the Delphi technique.	By inventorying and analyzing available human & material resources, solution strategies & procedural designs for relevance, feasibility & economy; and by using such methods as literature search, visits to exemplary programs, advocate teams, & pilot trials.	By monitoring the activity's potential procedural barriers & remaining alert to unanticipated ones, by obtaining specified information for programmed decisions, by describing the actual process, & by continually interacting with & observing the activities of project staff.	By defining operationally & measuring outcomes criteria, by collecting judgments of outcomes from stakeholders, & by performing both qualitative & quantitative analyses.

Table 3.1: Four types of evaluation in the CIPP model (Extracted from Stufflebeam, 1983, p.129)

The CIPP model adopts a very broad approach to evaluation with the inclusion of a wide range of perspectives. Context evaluation involves needs analysis for targets and matching programme objectives to targets' needs. Input evaluation resembles intrinsic evaluation but is broader in scope. It attempts to identify and weigh alternative approaches to program designs as well as identifying constraints and potentially available resources within the system. Process evaluation checks implementation so as to provide feedback to planners. This guides modifications and changes as the circumstances warrant, and assesses regularly the extent to which participants are capable of carrying out their roles. Process evaluation records are an important source of information for interpreting product evaluation results. Finally, product evaluation incorporates both goal free and goal-based evaluation, by exploring both intended and unintended outcomes.

The CIPP model represents a management approach to education evaluation. It stresses the systematic process toward decision-making based on contextual analysis and evaluation of process and product. Implicit in this model is the view that appropriate input is instrumental in producing learning outcomes. It resembles Stake's Countenance Model but adopts a wider scope of evaluation. It facilitates evaluators to pay attention to every stage of the curriculum process, hence ensuring that problems inherent in each stage could be identified and remedied as quickly as possible. This makes the CIPP model ideal for formative evaluation.

Illuminative Evaluation Model

This is an evaluation approach based on the interpretive or naturalistic paradigm which argues against a mechanistic view of world and hence the positivistic approach to educational evaluation. This model was originally developed by Parlett and Hamilton (1977). It seeks to illuminate the important features of a program and the problems within it.

The model involves three stages. The first stage is observation. The evaluator takes a detailed look at the curriculum and describes the context within which it is delivered. All factors that might influence the curriculum are studied including curriculum materials, teaching and learning styles, and assessment methods.

The second stage is further inquiry. The evaluator will focus on the important aspects to be evaluated and approach individual stakeholders to understand whether the curriculum works and the reasons why. The evaluator progressively focuses on emerging issues while examining the curriculum in action. The methods of data collection include examining school documents and students' work, and interviews and questionnaires with teachers.

The third stage is explanation. The evaluator does not pass judgment on the curriculum, but rather provides analysis of what is happening and attempts to explain why. Finally, the evaluator will present the findings to his clients for decision-making.

In the model, the evaluator studies a curriculum in its natural setting, with no a priori theory or hypotheses. This is based on the assumption that curriculum or education is a set of interactions that are complex and dynamic. Hence the evaluation has to be approached holistically as the system targeted cannot be broken down into parts for objective measurement. The evaluation is illuminative in a sense that in-depth encounters with the curriculum unveil its unintended and subtle parts.

The problems associated with this type of evaluation are: subjectivity of the researcher, possible effects of the presence of the researcher on the conduct of the programme, the application to only small scale studies, and consequently, limitations in generalizing the findings to other situations. Partlett and Hamilton (1977) dismiss these by arguing that, first, subjectivity can be minimized by cross checking of data, e.g. by outside researchers and by making criteria and evidence explicit for others to judge the quality of the evaluation findings. Second, evaluators should attempt to be "non-obstrusive without being secretive", to be "supportive without being collusive", and to be "non-doctrinaire without appearing unsympathetic", hence avoiding disturbances to the programme (p.19). Third, this model can be applied on a wide scale by focusing on a small sample of schools first. As the issues become more focused, a wider sample can be targeted by using other data collection methods such as questionnaires.

Responsive evaluation

Like the Illuminative Evaluation Model, responsive evaluation does not regard outcome evaluation as the only means to prove the worth of a programme. This was proposed by Stake (1983) who has shifted to a more naturalistic evaluation approach after he put forward the Countenance Model. He states,

> *" ...I believe it is not always best to think of the instrumental value of education as a basis for evaluating it. The "payoff" may be diffuse, long-delayed; or it may be ever beyond the scrutiny of evaluators." (Stake 1983, p.294)*

Stake considers an educational evaluation to be "responsive" if

> *"it orients more directly to program activities than to program intents, if it responds to audience requirements for information, and if the different value perspectives of the people at hand are referred to in reporting the success and failure of the program." (Stake 1983, p.292).*

In responsive evaluation, the evaluator is expected to be active in construing events and conceptualizing issues, and in stimulating thoughts from the target, thereby enriching his or her findings. The responsive model employs the stance of a naturalist, and the strategies common to ethnographic studies in collecting data.

The evaluator identifies certain issues or potential problems for incorporation into a data-collection plan. Data collection is mainly by observation, interview and case studies. Despite the shift in approach from the Countenance Model, Stake still uses the three categories: antecedents, transactions and outcomes as the framework for collecting data, yet the observed outcomes are not measured and judged against intended outcomes as proposed in the Countenance Model. By analysis of the data, the major issues or questions will be identified. The evaluator will then present a tentative report to the sponsors. He will further analyze their reactions and investigate important concerns more fully, emphasizing both conflicting and supporting evidence, before making a final report. To minimize subjectivity, the evaluator has to validate his portrayal with the persons concerned.

The Responsive Evaluation Model focuses on all levels of curriculum. It employs both goal-free and goal-based evaluation. The evaluator plays the role of an objective observer who, presumably, should not be influenced by the goals or values of the curriculum planners or sponsors. This model faces similar problems to the previous model which may be resolved using similar strategies.

3.2.3 Methods of curriculum evaluation

Evaluation strategies or models could guide the design of methods which put evaluation into action. I would like to draw upon five distinctive models or methods summarized by West (1975) for data collection and discuss their usefulness. These method models are 'Agricultural Botany', 'Social Anthropology', 'Interaction', 'Productivity' and 'Adversary'.

The 'Agricultural Botany' model emphasizes testing of student outcomes by comparing experimental and control groups to establish the superiority of a program over another. Careful control of variables to ensure validity and reliability of the findings is necessary though it is exceedingly difficult to achieve given the complexity of the perceptions and actions of human beings. This model is particularly useful for outcome evaluation based on a scientific-positivistic paradigm.

The 'Social Anthropology' model is commonly used by evaluators adopting the illuminative and responsive evaluation strategy. This approach assumes that peoples' decisions or behaviours can only be understood from their own points of view and total objectivity cannot be achieved. Hence, data are obtained through such methods as interviews, conversations, questionnaires, observation schedules, checklists and analysis of children's work. Its strength lies in the close relevance to a real situation and the power to collect very rich data. However, the other side of the coin is that it tends to generate excessive data which may be irrelevant, thus posing difficulties for the evaluator to establish relevant links and relationships. It also suffers from reliability and validity problems.

The 'Interaction' model is also based on an interpretive paradigm. It focuses on interactions among teacher, pupils and the curriculum, which are seen as an interactive system. The nature of interactions are categorized, analysed and interpreted to create a model of relationships. The evaluator is considered to be "a connoisseur" who emphasizes the relationship among teachers, students, curriculum materials and teaching methods (Eisner 1983). Again the methods utilized and the problems of validity and reliability are similar to those associated with the 'Social Anthropology' model.

The 'Productivity' model advocates that evaluation be based on "input-output" terms.

Cost-effectiveness is assessed by estimating the cost of implementation and comparing it with the level of attainment of the learning objectives. The problem with this is the difficulty to describe clearly the outputs of the curriculum in terms relating to attained objectives. Finally, the 'Adversary' model adopts the viewpoint that the curriculum should be analyzed from both a supportive point of view and a negative point of view. That is, both arguments and counterarguments should be taken into account during evaluation. This approach could be applied in most evaluation models as described previously. This model is pragmatic and reflect the reality of curriculum changes, hence it should be widely applicable in most evaluation studies.

3.2.4 Summary

Evaluation methods based on different paradigms have their own merits and demerits in illuminating different aspects of the curriculum. Models or methods based on the positivistic paradigm seem to provide more reliable information for drawing inferences about cause-effect relationships or the worth of a curriculum in terms of the achievement of curriculum objectives. This is evidenced in the widespread use of standardized tests in curriculum evaluation (Madaus and Kellagham 1992). On the other hand, evaluation models based on the interpretive paradigm are more effective in revealing the interactions within a curriculum in a holistic manner. Although these models tend to refrain from passing judgment on the worthiness of the curriculum, by exploring deeply into the happenings within the programmes, they could reveal the intricacy of the intended or unintended transactions. This makes these naturalistic models more effective in identifying issues or problems arising in the implementation stage.

The positivistic and interpretive paradigms on which the evaluation models and methods are based are not as incompatible as they seem to be. Husen (1988, p 20) maintains that the "two main paradigms are not exclusive, but complementary to each other". Walker and Evers (1988) even argue for an epistemological unity of educational research, having recognized the limitations of the paradigm perspectives when applied to education. This implies that an eclectic approach based on both positivist and interpretive paradigms is most suitable for curriculum evaluation which aims at a more complete illumination of outcomes and the process.

If one adopts the view that the curriculum consists of three levels: intended, implemented and achieved curricula as described earlier, it is logical to assume that a single model based on a single paradigm would not be sufficient to reveal the whole process and its strengths or problematic areas. From the review of evaluation models, it appears that the intended curriculum can best be illuminated by intrinsic evaluation, which helps to identify both opportunities and potential problems, hence predicting implemented practices. The implemented curriculum could be elicited through qualitative methods based on an interpretive paradigm in view of the diversity of teaching practices and their rationale behind. The data obtained at this level could also inform the intended curriculum and verify the predictions made by intrinsic evaluation. Finally, evidence concerning the intended and implemented curricula could be used to explain the achieved curriculum as revealed by outcome evaluation.

3.3 Science curriculum evaluation

Evaluation studies have been carried out at both international and national levels. The latter includes evaluation of national curricula as well as large-scale curriculum projects. In this section, some of these studies are reviewed to provide a better understanding of how different evaluation strategies and methods could achieve different purposes, and of their strengths and weaknesses when applied to different contexts. Although the outcomes of these studies are less important than the methodology for the present purpose, they provide evidence to demonstrate the strengths and limitations of alternative designs. In the final part of this section, I will synthesize the salient points drawn from the review and suggest how these are applied to the design of evaluation framework and methodology for the present study.

3.3.1 International studies

The IEA conducted two international science studies in the 1980s and 1990s to investigate students' achievement in science: SISS and TIMSS. As TIMSS is the latest version of these studies and was developed on the basis of SISS, only TIMSS was reviewed in this section.

The TIMSS

The TIMSS was conducted in 1995 to investigate mathematics and science education in different countries at three population levels. Populations 1 and 2 comprise 9 and 13 years old students respectively. Population 3 comprises students in their last year of secondary school that is aged 17-19. The conceptual framework of the study consists of the three levels of the curriculum, namely the intended, implemented and achieved curriculum. This framework was partly derived from the notions of antecedents, transactions and outcomes as described in the Countenance Model of Stake (Robitaille and Garden 1996). The intention of adopting this evaluation framework is to achieve "a better understanding of what mathematics and science can be taught and learned, and of the factors that contribute to, constrain, or promote that learning" (Robitaille, Schmidt et al. 1993, p.17). Fig. 3.2 shows this conceptual framework.

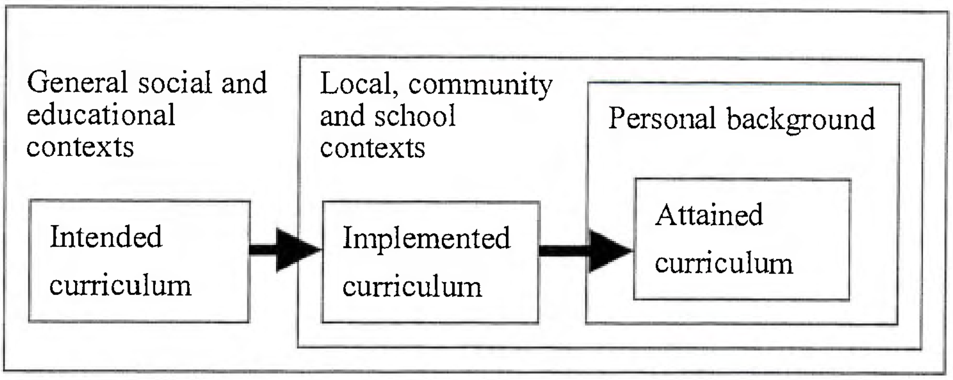

Fig. 3.2 : Conceptual framework for TIMSS (Extracted from Robitaille et al 1993 p.37)

Data about intended curriculum were collected from system-level questionnaires which focused on the organizational structure, courses and demographics, and from expert questionnaires which provided information about national-level curriculum plans, reforms and issues with respect to science curricula including national assessment practices. These were regarded as important because they provide useful information on contexts of different systems and assist countries in evaluating their performance and in drawing conclusions about the changes that might be warranted. Each country also performed detailed analyses of curriculum guides and prescribed textbooks with a complex coding system corresponding to three aspects: *content*, *performance expectations* and *perspectives*. These three aspects were used to characterize both learning activities and assessment items. The content aspect includes the major areas of study; the performance expectation aspect includes cognitive understanding and process skills; the perspective aspect covers areas concerning attitudes, careers, participation and interest (Robitaille, Schmidt et al. 1993, p.46). In addition, the test items for assessing the achieved curriculum were reviewed to ensure matching with the intended curriculum.

Teacher questionnaires were used to elicit information about the implemented curriculum. They addressed teachers' background, beliefs about pedagogy and instructional practices. Teachers were also asked to furnish information on "opportunity to learn", that is whether the content of the achievement tests had been actually taught. The achieved outcomes were measured using multiple-choice and free-response items, as well as performance tasks. In addition, student attitudes were assessed through a questionnaire.

Such complex study as TIMSS necessitates the adoption of both quantitative and qualitative data gathering devices. The strength of the design lies in the comprehensive conceptual framework which was grounded in theories of educational evaluation, in this case Stake's Countenance model. This provides a clear guide for data collection and analyses. The sampling procedure also allows the findings to be generalized to a wider school population. The scope of the study is comprehensive and caters for all three levels of curriculum.

One could argue that there are limitations to this large-scale study, as the evaluation criteria used in TIMSS are not totally consistent with the curricular objectives of individual participating countries, hence resulting in unfairness. This limitation is offset to a certain extent by taking into account the "opportunity to learn" factor in the study. Nevertheless, the value of TIMSS is to broaden the perspectives of participating countries for evaluating their own curricula.

Probably the main weakness with this large-scale international study is that all data collecting devices were standardized to such an extent that no provisions were allowed for probing more in-depth data, for example, through interviews with teachers and students. As Keys (1999) implies, TIMSS findings are limited because no data were collected at the classroom level. Cheng and Cheung (1999, p.235) also suggest that "national in-depth case studies should be important for understanding the complex process and identifying excellent practices for educational effectiveness".

3.3.2. Evaluations of national curricula and large-scale projects

In contrast with international studies, evaluation of national curricula is more able to pinpoint the contextual aspects and the intended goals of the curriculum. I review a number of them. I could not claim my sources of evaluation studies to be representative as the samples selected are mainly the well-documented ones. I did make a special effort to select studies carried out in a wide range of countries. I trust they could provide valuable insights into the goals of the evaluators, and the methodology used for achieving these goals in their unique contexts. In the following review, I focus particularly on the nature of the data collected in individual national-level studies, and on the way in which inferences were drawn on the effectiveness of the curriculum reform. For the sake of clarity, the studies under review are arranged in a sequential manner which reflects a shift of focus from the intended curriculum to the achieved curriculum, and from a narrower scope of evaluation to a wider scope.

Science curriculum in Nigeria (1985)

The evaluation study of the 1985 Nigerian curriculum demonstrates the value of an intrinsic evaluation in identifying potential problems of a curriculum before implementation. This study took the form of intrinsic analysis of the official syllabus, which included detailed analyses of aims and objectives in respect of their appropriateness and clarity, and of the congruence between the two (Adamu 1989). The findings show that the aims and objectives were set out in a manner that were too complicated and lacked clarity. The problems identified in this study have been discussed in Section 2.4. These problems were aggravated by the fact that no textbooks were there to support the syllabus guidelines in the first few years of implementation, nor was there any monitoring mechanism for determining whether the outcomes matched the aims and objectives.

Science curriculum in Lebanon

Another example of intrinsic evaluation is the study conducted by BouFaoule (2000) on the new Lebanese science curriculum for students in Grade 1-12. The purpose was to investigate the balance of scientific literacy themes in the curriculum in order to identify its potential to prepare scientifically literate citizens. The method was to analyse the goals, introduction, objectives, instructional objectives and activities and categorize them according to the four aspects of scientific literacy used by Chiapetta, Sethna et al (1993): *knowledge of science*, *the investigative nature of science*, *science as a way of thinking*, and *the interaction of science, technology and society.*

By comparing the percentage distribution of these four aspects in different areas of the curriculum, it was found that although *science as a way of thinking* was employed in the general objectives, the more detailed the curriculum becomes, the less evident is the emphasis on this aspect. This study thus reveals inconsistencies in translating general objectives into specific objectives and into learning activities. This illustrates the utility of intrinsic evaluation in revealing inconsistency within the intended curriculum. Hence, it could help to predict the extent to which the intended curriculum could fulfill the objectives when implemented. The study could to a certain extent predict the likelihood that the intended curriculum could fulfill the general objectives when implemented.

The 1991 version of National Curriculum in England and Wales

Russell, Qualter et al (1995) reported a study commissioned by the National Curriculum Council of the UK on the 1991 version of National Curriculum in England and Wales as a result of problems identified in a preliminary survey. The goals were to evaluate implementation with respect to coverage, progression and differentiation, to identify problems inherent in the curriculum itself, or related to implementations, and to make recommendations. Hence, the evaluation was necessarily targeted at the intended and implemented curriculum.

Taking advantage on the findings of a preliminary survey, the evaluators adopted an in-depth approach, based on an interpretive paradigm, to further investigate three problematic areas identified by the sponsor. The samples were made up of teachers and students. Teachers' interviews and questionnaires were used to broaden the sample and extend the lines of enquiry. Case studies were carried out in 22 schools through interviews, document examination, attendance at staff meetings, and lesson observations and student interviews. A more ingenious method used was the setting up of teacher progression study groups to study how progression could be achieved in practice. Teachers teaching at different key stages were arranged to teach the same topic within the same time period. They then met with each other to discuss how progression in the topic could best be achieved and to find out a workable way of addressing the issue of progression across different stages or levels. This method effectively extended the scope of the study beyond curriculum evaluation to improving the curriculum based on the problems identified.

The evaluators concluded from the study that some of the problems were due to the design of the curriculum, and others to a lack of background in teachers for some of the topics and a lack of coherent interpretation. This study underscores the importance of evaluating classroom practices for reflecting on the problems of the intended curriculum. The assumption is that good intentions should be firmly grounded in practices, and practicable ways for achieving these could be explored through evaluative studies. This is particularly true in evaluating and improving the design of areas as complex and delicate as progression in the curriculum document.

Junior secondary science syllabus in Botswana

Prophet (1990) reported an evaluation study on the Botswanan reform in junior secondary science which replaced an old curriculum based on Scottish Integrated Science with a more pupil-centred curriculum, emphasizing the development of observation and communication skills. The study focused mainly on the implemented curriculum. It took an ethnographic approach in exploring life in the classroom of junior secondary schools under the new curriculum (Prophet 1990). The methods used include lesson observations and open-ended interviews with teachers, pupils and school heads.

Through the evaluators' exploration of the interactions between teachers and students, prominent discrepancies in actual practices were observed. Teaching was didactic and students' role was passive. There were few opportunities for children to verbalize their own ideas. The teachers' practice of adhering rigidly to "correct" scientific answers in their discourse effectively moved students away from the spirit of inquiry and reinforced their lack of ability to express themselves. From the study, the researcher inferred that the discrepancies stemmed from the use of a second language, English, as the learning medium, and from the incompatibility of modern science with traditional Botswana culture that discouraged innovative and critical attitudes. This study shows that evaluation at the implementation level is useful for revealing the gap between curriculum intentions and actual practices. Moreover, an ethnographic approach has the potential of exploring more in-depth causes for non-compliance with the intended curriculum.

Science and Technology in Society (SATIS)

The Association for Science Education of the UK published the SATIS for the age 14 to 16. Adopting an STS approach, it is a set of resource materials for teachers that link science with the real world. Two evaluations were conducted in 1987 and 1989 respectively to assess the usage of the curriculum materials in schools and the feedback from stakeholders including teachers and students (Walker 1990). The findings were intended to provide guidance on further revision and extension of the project, to generate input to other current projects, and to provide food for thought for future planning. The evaluations employed two methods: in-depth questionnaire, and interviews with teachers and students. The questionnaire was sent to schools to obtain feedback on individual units including student interest, concept level, teaching sequence, language level and teaching/learning method. Teachers were interviewed to collect their opinions about the materials, and students were asked to express their degree of interest in the course. These were supplemented with classroom observations on the units actually in use.

According to the evaluators, SATIS was widely used by schools. The content and units were in general useful to supplement existing practices. The new teaching methods were in general welcome by teachers though some, such as role-plays and debates on social issues were less readily accepted than others like data management. The evaluation methods seemed to be very successful in drawing in-depth comments from teachers.

Instead of measuring students' outcomes quantitatively, qualitative methods were used to elicit feedback from users. This choice of evaluation strategies was probably related to the nature of the curriculum materials, which were designed to supplement existing practices and to arouse interests of students, rather than serving as a self-contained curriculum.

Science curriculum in Uganda

Following a different line of inquiry, Black and Atwarn-Okello (1998) evaluated the science curriculum in Uganda by focusing on the implemented practices and the outcomes of the curriculum, using one to inform the other. Realizing that the last curriculum reform had already occurred for a number of years, the evaluation sought to determine the extent to which these emphases were translated into teaching practices. This was done through informal classroom observations and discussion with teachers to check whether their views were incorporated into their teaching practices. As a measure to check the "success" of the curriculum, the evaluators assessed whether the perceptions of science and science education held by various stakeholders including teachers, students, parents, and employers were in agreement with one another and in congruence with current thinking. Different stakeholders' perceptions of science and science teaching in terms of memorization, problem solving, and preparing young people at work were elicited through questionnaire surveys.

The results showed that discrepancies existed between teachers' and students' perceptions. The reasons were due to poor science teaching facilities, large classes, traditional examination syllabuses, and the lack of equipment, classrooms and facilities. This study concerns with the implemented and achieved curricula. It demonstrates the use of consistency analysis of different stakeholders' perceptions as a reflection of curriculum outcomes, and using this as a basis to explore the causes for the apparent failure to achieve the curricular goals.

Science-A Process Approach (SAPA) in the US

The SAPA was an American project for elementary schools, which adopted a process approach to teaching and learning science. Wideen (1975) conducted a summative evaluation to assess the worth of the curriculum when compared with traditional curricula by assessing the achieved curriculum. A broad range of criteria were employed to reflect the outcomes, including student attitudes toward and interest in science, student perceived teaching and learning environment, and understanding of science knowledge and scientific processes. A quasi-experimental study was conducted using a non-equivalent control group design, and co-variance techniques were employed to control for the variation of the two groups using pre-test scores as covariates.

The results indicated that students exposed to SAPA performed better on cognitive and process oriented tasks. There was a negative effect on students' interest in science and perception of teaching-learning environment for high achieving students, but the reverse was true for low achieving students. Gender effect was significant, with boys showing greater interest in science.

A number of parameters were measured in this study to reflect the different aspects of student outcomes, allowing a more holistic evaluation of the achieved curriculum. This study also illustrates the application of non-equivalent experimental-control group design and the use of statistical means to control threat to validity due to non-random sampling.

Science: The Salters' Approach in the UK

The Salters' Curriculum development projects provide complete applications-led science for students age 11 to 18. Campbell, Lazonby et al (1994) reported a case study of the developmental process of the project which took the approach of a retrospective analysis of the development from a review of the theoretical underpinning and design criteria to curriculum evaluation. The evaluation consisted of formative evaluation of individual lessons and units which focused on teachers' experiences in using the materials.

The researchers highlighted a number of difficulties inherent in the evaluation of a long course like the Salters' project. First, a long course had diversified objectives, some more general and the others more specific. Second, it used a variety of teaching and learning strategies to achieve its aims, so that it was difficult to attribute individual outcomes to specific characteristics of the design. Third, students taking the course had no experience of other courses, hence comparison with other courses was not possible. Fourth, teachers who used this course were likely to be biased towards it, and conversely those who had not opted for the course had insufficient knowledge about it to give any useful comments. In the light of these constraints, the evaluators use several criteria to determine success, including the number of users and their satisfaction with the course after several years of use, the number and results of students entering national examinations testing their progression in the course, and the number of students who chose to continue studying science after completing their GCSE course.

A number of researchers evaluated the effectiveness of the Salters' project using different approaches. Ramsden (1992, 1994) obtained structured feedback from teachers and students through questionnaire and interviews. Borgford (1992, from Campbell, p.442) carried out field research to investigate teachers' perceptions of the Salters' approach, the management issues concerned, teachers' perceptions of their changed roles, and students' motivation and understanding. As discussed above, it is not easy to find evidence from general outcomes for the effectiveness of specific strategies employed in a long course. Barker and Millar (1999) got around this by exploring changes in students' thinking about basic chemical ideas in a longitudinal study of 250 students following the Salters' Advanced Chemistry course. Diagnostic tests were used to probe students' understanding of a range of chemistry topics at different stages of the course. The test results were validated by student interviews. The findings indicated that students' understanding improved steadily as the course progresses, but some seemed to be resistant to change despite interventions, suggesting a continuing need for reviewing teaching approaches.

The evaluation of SALTERS highlights the problems in evaluating a long course. The evaluators were able to isolate specific aspects of the curriculum for evaluation, and to approach them through different means.

Science 5-13 in the UK

This is a formative evaluation carried out at different stages of development of the Science 5-13 Project (Harlen 1975). The planners themselves did the evaluation. The goals were to gauge the effectiveness of the curriculum materials in helping teachers to provide intended learning experiences and to identify changes to be made in further trials. To achieve these goals, the evaluation was targeted at all three levels of the curriculum. At the intended curriculum level, evaluation of the suitability of the written materials was based on teachers' comments. For the implemented curriculum, data on how teachers planned their lessons, interaction among teachers, students and the materials, and the learning environment were collected through teacher questionnaire, school visits and class observations. The achieved curriculum was evaluated by an experimental-control study using pre-test and post-test to collect evidence for improvement in cognitive abilities and attitudes. In addition, diagnostic statements were designed to help teachers determine and record students' progress.

The findings showed that pupils' knowledge, skills and attitudes increased significantly in the experimental group compared with the control group, leading the evaluators to conclude that the materials were effective. Despite this proven effect, it was found that teachers' willingness to adopt methods for enabling children to learn through more active inquiry had not changed with the use of the materials. This finding implies that evaluating the achieved outcomes alone is not sufficient to reveal the full impact of a reform including its underlying problems. The study raised an important issue which has implications for curriculum evaluation. That is, even though the curriculum materials are implemented, it does not necessarily imply that teachers' attitudes change as desired.

Physics Curriculum Development Project (PLON) in the Netherlands

Van Aaist and Wierstra (1979) reported an evaluation study for the trial version of the Physics Curriculum Development Project (PLON) of the State University of Utrecht in the Netherlands. The project was aimed to familiarize students aged 12-17 with mechanical constructions in real life through making and investigating the constructions themselves. Adopting Stake's model of countenance, this study looked for congruence or incongruence between intended data and observed data. Pupil questionnaires were used to explore pupils' views about investigative activities, problems encountered, teacher-pupil interactions, and activities liked or disliked. Pre- and post-tests on students' abilities to solve problems were conducted to evaluate the achieved curriculum. Moreover, students were interviewed to explore the connections between their responses and class activities. Class observations and teacher interviews were also conducted. These interviews were based on the observation of teachers' use of curriculum materials, groupings, and teachers' opinions of the attractiveness of the materials. Evaluation continued as revisions were made, focusing increasingly on specific issues. The results indicated that the materials were not so effective in helping students understand the concepts behind their constructions and appreciate the investigations.

Two features of the above evaluation study are noteworthy. First, student interviews were used to draw connections between student outcomes and classroom practice. Second, the differentiation of the evaluation into different phases allowed more in-depth focusing on problematic areas. This aspect of the study to a certain extent reflects the illuminative evaluation strategy in which the evaluator progressively focuses on emerging issues while examining the curriculum in action.

In the next section, I turn my focus to previous evaluative studies on the IS curriculum of Hong Kong.

3.3.3 Science curriculum evaluation in Hong Kong

Evaluation studies were conducted when the old curriculum was in the pilot stage. Apart from these, Hong Kong also participated in the SISS and TIMSS. As the methodology and results of the two international studies have been described in Section 2.5 (p 69) and 3.3.1 (p 91) respectively, only the local studies will be reported here.

The Science Subjects Section of the Advisory Inspectorate of the Education Department conducted an evaluation study when the old curriculum was still in its pilot stage (HKED 1974). Twenty schools took part in the pilot stage, most of which were elite schools with students of higher abilities. The curriculum evaluation comprised three major parts: (1) visits by science inspectors to schools to observe classes and discuss with teachers; (2) a teacher questionnaire to elicit teachers' comments on different aspects of the syllabus; (3) multiple choice progressive tests to assess students' achievements. Two trial reports were produced from the study. The first reported the overall outcomes of the evaluation including school visits and teacher questionnaire, while the second deals with the multiple choice progressive tests in detail.

As indicated in the first report, the school visits collected good feedback from both teachers and students, who showed great interest in the curriculum. Students found little difficulty in understanding the worksheets. Shortage of equipment was found to be the main difficulty. The progressive tests showed that even students in low-achieving schools scored more than 50% in the tests. Despite these positive outcomes, the teacher survey indicates that 77.7% of respondents agreed or strongly agreed that "a stage-managed discovery approach with 40+ students in a class is impossible".

The second report shows that based on an in-depth analysis of a private school, the mean score difference between girls and boys was insignificant for the three tests combined, indicating no gender difference in achievements in Integrated Science. However, the teacher factor was proved to be important in influencing the scores as analysis of variance shows significant differences between classes taught by different teachers. Moreover, the achievement in objectives concerning concept formation and abstract thinking were not satisfactory. They were thought to fall below the standard of children at the age of 12 to 14 and further consideration of their inclusion was recommended (HKED 1976).

Despite these negative outcomes of the trials, the evaluators draw the following conclusion:

> *After a full-year trial in 20 pilot schools, it has been found that in general, the integrated science course is welcomed by principals, teachers and pupils. The course has developed a new approach in teaching/learning science at the junior secondary level, which enables the pupils to achieve a real understanding of the basic scientific concepts. Since the pilot schools were carefully selected by a cross-section of our school population it has also been discovered that the integrated science course could cater for pupils of a wide range of abilities. (HKED 1974, p.32)*

Apparently this conclusion is subjective, and to a certain extent, biased. It failed to address the large variation in teachers' practices, the under-performance of students in concept formation and abstract thinking, and the constraints perceived by teachers regarding class size. This may be attributable to the role conflict of the curriculum planners who served also as programme evaluators. By painting a rosy picture of the SISP curriculum, this evaluation study paved the way for its full implementation in the late 1970s.

In addition to the official study, Tsoi (1980) conducted an independent evaluation study on the effectiveness of the I.S. curriculum when it was still at the pilot stage. He employed a non-equivalent experimental-control group design to establish whether there was improvement in schools using the new curriculum. Students' performance in cognitive ability in science measured by a self-designed achievement test was taken as the criterion for improvement. Four groups of students, each comprising 5-6 classes, were involved in comparison: (1) pilot Anglo-Chinese (former name for EMI before the new language policy became mandatory) schools using the new curriculum and with additional equipment budget; (2) Anglo-Chinese (EMI) schools taking the new curriculum but without additional equipment budget; (3) Chinese-middle (former name for CMI) schools using the new curriculum but without additional equipment budget); and (4) Anglo-Chinese schools using the traditional science curriculum. The classes of the four groups were matched with each other according to pretest results. The test was administered at the beginning, in the middle, and at the end of the school year. The findings echo the previous ones in that teachers were the most important factor affecting students' overall achievement. The three new curriculum groups showed cognitive gains in a wider range of topics than the traditional group. The overall improvement of Group 1 was the highest, but Group 2 was not different from Group 4. This seemed to indicate that the availability of additional equipment support was most crucial to the effective implementation of the I.S. curriculum.

Although the study reveals that there seemed to be an advantage of the I.S. curriculum over the traditional one, the usefulness of the data may be limited by certain constraints. First, students of Chinese-middle schools were generally of poorer ability than those of the

Anglo-Chinese schools. This should be taken into account when comparing the results of this group with the others. Second, despite the increase in emphasis on laboratory skills in the new IS curriculum, the study relied only on paper-and-pencil tests to assess cognitive abilities. No practical activities or performance assessment were conducted, hence the outcomes did not reflect the range of student outcomes, in particular, the skills that were stressed in the IS curriculum. Third, as the study focused only on the achieved curriculum, it tells nothing about other levels of curriculum, hence providing little clues for explaining the outcomes.

As for the new science curriculum implemented in 2000, no formal formative evaluation had been conducted before its full implementation. A questionnaire survey was conducted after the draft version of the syllabus had been sent to schools for consultation. The results were not, however, released to the public.

3.3.4 Overview of evaluation studies

Several important issues emerge from the previous review on evaluation studies, contributing to the design of this study. Some concern the levels of curriculum targeted while others are related to the methodology employed. These issues to a large extent echo the insights drawn from evaluation theories and models as summarized in Section 3.2.4 (p.89). Overall, the review in this section shows that evaluation at different curriculum levels is capable of yielding valuable feedback about a reform, which are complementary to each other.

Study of the intended curriculum (e.g. science curriculum in Nigeria) reveals opportunities or potential problems when the curriculum is put into practice. The review indicates that intrinsic evaluation is a powerful tool for evaluating the intended curriculum, particularly in revealing the emphases of the curriculum and in checking consistency and clarity of the syllabus content.

Studies focusing on the implemented curriculum are useful in two aspects. First, they inform the appropriateness of the intended curriculum because some problems inherent in the curriculum design will unfold only when they are put into practice, particularly in areas where both theory and empirical evidence are lacking. One typical example is the notion of progression in the national curriculum in England and Wales (1991 version). Second, these studies reveal also the strengths and weaknesses of the school system in putting theory into practice, which seems to be a major issue identified by some of the studies (e.g. Botswana junior secondary science, and science curriculum in Uganda). These strengths and weaknesses could provide explanations for the achieved outcomes. Evaluation at the achieved curriculum provides more concrete evidence about the effectiveness of the curriculum and this should be viewed in conjunction with findings at the other two levels for formulating possible explanations.

One logical inference emerging from the above discussion is that study at each level of curriculum could illuminate each other, thus allowing a more complete picture to be drawn. Hence, those studies receiving inputs from all the three levels appear most promising for drawing reliable inferences about a curriculum reform (e.g. Science 5-13 and PLON).

As for the methodology used in these studies, despite the clear demarcation between positivistic and interpretive paradigms in theory, in reality the distinction between the two is blurred. Many evaluators actually employed multiple methods to collect quantitative as well as qualitative data across different levels of curriculum. This implies that in a practical sense, the two paradigms could be integrated to provide a better illumination of a curriculum. The methods based on the positivistic paradigm are able to gather more objective evidence of the outcomes, whereas those methods pertaining to the interpretive paradigm allows exploration of factors behind these outcomes. From the review, it seems that the more diversified the methods used, the more informative the data will be, and the clearer the picture becomes.

3.4 Summary

Theories and practices of curriculum evaluation have shed light on the principles of and alternative approaches to an effective evaluation process. The essential principle distilled from the review in this chapter is that curriculum evaluation should address not only the product but also the intrinsic quality of the intended curriculum and the implementation process. This allows more complete illumination of the curriculum under study including the identification of problems in design and constraints within the system, which is vital for improving the curriculum. The review findings imply that some of these constraints may be deeply rooted in our own culture, which are resilient to changes. Ignoring them would lead to recurrence of reforms without achieving the desired outcomes. As far as evaluation methodology is concerned, the review implies that different research paradigms need not be regarded as mutually exclusive. On the contrary, curriculum evaluation could be viewed as a kind of educational problem-solving which needs to draw on a repertoire of methods offered by seemingly conflicting research paradigms.

To avoid bias in data interpretation and hence in the conclusion drawn, it is important for evaluators to be aware of their own assumptions or hidden agenda and the way they may influence the choice of evaluation strategies, data interpretation and judgment about the worth of the curriculum. By the same token, keeping a "sharp" eye on potential threats to validity and reliability is essential to making the evaluation a credible one.

The findings from the review of local science curriculum evaluation studies reflect that Hong Kong has yet to gain the expertise and experiences in applying sound principles for evaluating its own curricula. There is an urgent need to develop the necessary framework and methodology for conducting curriculum evaluation in Hong Kong's context, drawing on the theoretical perspectives and practical aspects reviewed in this chapter. This should be able to illuminate different levels of curriculum with sufficient impartiality, reliability and validity. I will introduce this framework fully in the next chapter, which deals with the methodology part of this study.

Chapter 4: Methodology

4.1 Introduction

In this chapter, I will discuss my methodological design based on the solid ground laid by the review in Chapter 2 and 3. Before designing the research methods, I consider it crucial to formulate a framework that guides the design process. This framework should set clearly the direction and focus of the evaluation. This chapter thus comprises two parts: the framework for evaluation and the methodology employed.

4.2. Guiding frameworks for the evaluation

4.2.1 Overview

This section introduces the framework for designing the methodology of the present evaluation. The framework comprises two parts. First is a curriculum framework, which conceptualizes the curriculum as a process from initiation through implementation to outcome assessment. Second is an evaluation framework. It builds on the curriculum framework and incorporates evaluation decisions at different levels of curriculum, with the research questions indicated at appropriate points. I describe these two frameworks in turn.

4.2.2 The curriculum framework

The formulation of a curriculum framework allows me to view the current reform in the Hong Kong context, which facilitates the design of the evaluation. This framework as outlined in Fig. 4.1 is descended from the three-level conceptualisation of the curriculum as discussed in Chapter 2. Hence, it incorporates the intended, implemented and achieved curricula as the basic scaffolding. I also incorporate the important contextual factors leading to the current reform and the possible factors affecting its outcomes as informed by my review in Chapter 2. The potential influences of these factors are noted at various stages of the framework. Based on these, other factors unique to the Hong Kong context could be explored further. In order to fully reflect the dynamics behind the reform while taking into account local uniqueness as described in Chapter 1, the three curriculum levels are differentiated further into seven sub-levels. I coin different terms for them to reflect their unique roles in the curriculum process.

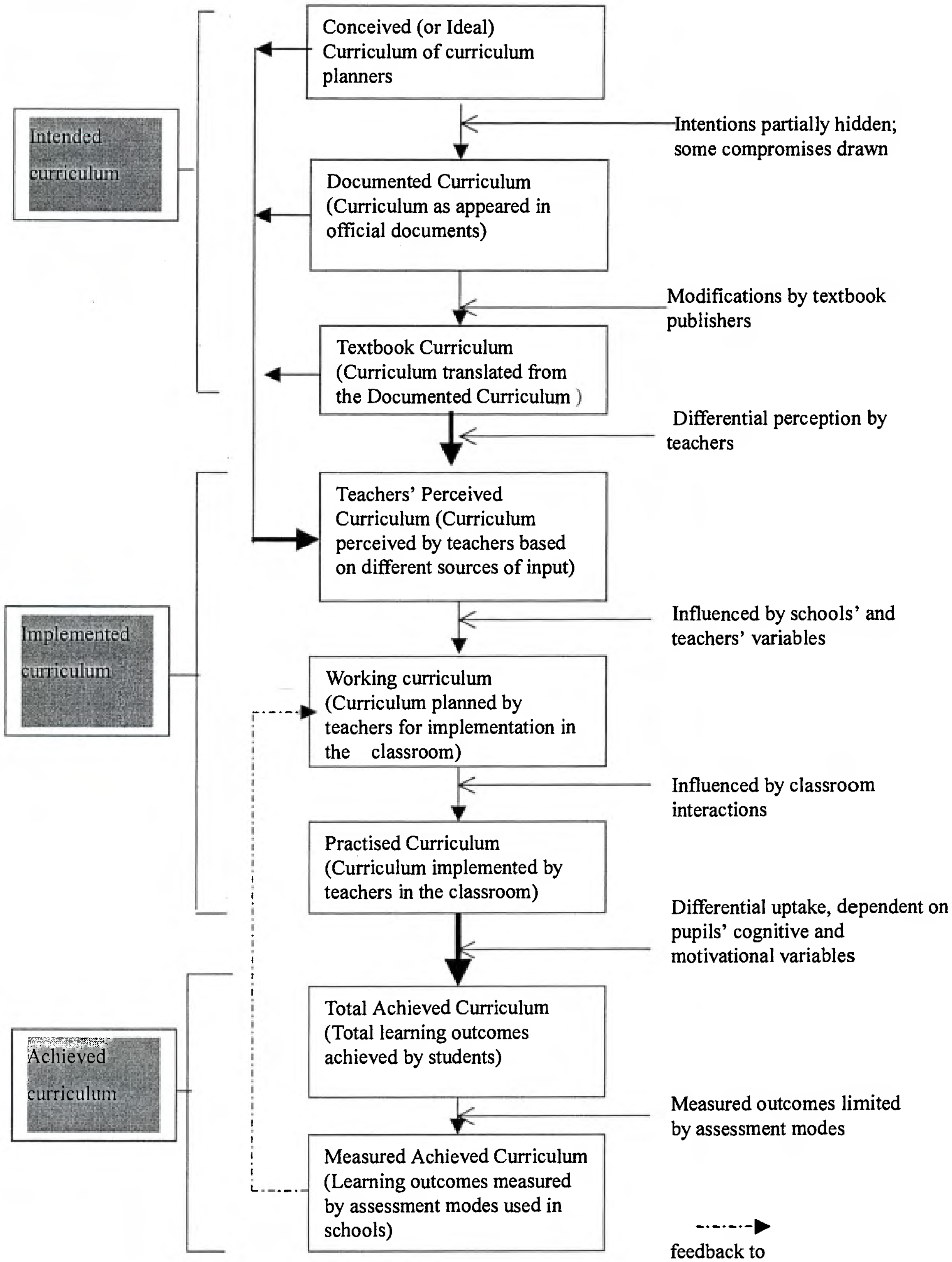

Fig. 4.1: The curriculum framework adopted in the present study

The intended curriculum

The intended curriculum comprises three sub-levels: the *conceived, documented* and the *textbook curriculum.* The *conceived curriculum* can be viewed as the vision or conceptualization of planners about the reform. It reflects the planners' philosophy, values, and theoretical positions on science knowledge and pedagogy, as well as the contextual factors underpinning the reform as reviewed in Section 2.3 (p.30). It also contains planners' assumptions about the causal relationships between intent and outcomes. This sub-level serves as a guide, or a template for the design of the *documented curriculum.*

The *documented curriculum* can be regarded as a vehicle for realizing the planners' vision. It appears as the official documents, or the syllabus. There may not be a perfect match between the conceived and documented because distortion may occur in translating ideas into a written form as evidenced in certain curricula reviewed in Section 2.4.1 (p.60).

The syllabus is translated into the *textbook curriculum* by publishers. Textbooks are used often in Hong Kong schools. This is due partly to the Chinese tradition which attaches great importance to learning from books, and partly to the heavy workload for Hong Kong secondary teachers. Teachers normally have to teach classes of about 40 students for about 30 periods per week. Hence, school-based curriculum development is an exception rather than the rule. Each student is expected to buy a textbook, usually accompanied by workbooks or worksheets, for each subject for use in every lesson. Strictly speaking, the textbook curriculum should not be considered as part of the intended curriculum. This is because textbook publishers are commercial enterprises with the freedom to choose the content. However, in Hong Kong, textbooks must comply with the requirements of the syllabus before the CDI would recommend them for school use. As such, the textbook can be considered as a sub-level of the intended curriculum.

The implemented curriculum

The implemented curriculum can be differentiated into three sub-levels: the *perceived*, *working* and *practised* curriculum. The *teachers' perceived curriculum* is the teachers' understanding of the intended curriculum. It may be informed by the *conceived*, *documented* or the *textbook* curriculum depending on their accessibility to the teacher. According to the theory of symbolic interaction, there is likely to be a gap between the intended and perceived curricula since teachers would selectively perceive, interpret, and place meaning upon information to form their own mental pictures (Spector 1984).

Teachers are likely to adapt their *perceived curriculum* according to his or her own practical knowledge (Van Driel 2001) before implementing it in the classroom. The *working curriculum* is a result of this adaptation, which includes all planned activities to be carried out in the classroom or laboratory. This working curriculum is similar to the "intended transactions" described by Stake in his Countenance model (Stake 1967). From the literature as detailed in Section 2.4.2 (p.62), this level could be influenced by both teacher and school variables.

Putting the *working curriculum* into practice leads to the *practised curriculum*. This is what Stake referred to as "actual transactions" (Stake 1967). This is the curriculum that actually occurs in the classroom. The *practised curriculum* is derived from the teacher's *working curriculum* but with varying degrees of modification due to classroom interactions between the teacher and students.

The achieved curriculum

The *achieved curriculum* can be differentiated into two sub-levels: the *total achieved* and the *measured achieved* curriculum The former represents the total learning outcomes achieved by students as a result of the practiced curriculum. To what extent is the *practiced curriculum* translated into the *total achieved curriculum* would be influenced to a great extent by student factors like students' cognitive abilities, attitudes toward science, self-concepts, motivational factors and peer influences. This sub-level usually cannot be fully disclosed by assessment measures due to the limited assessment modes used in Hong Kong schools. The part that is measured in schools constitutes the *measured achieved curriculum*. Ideally, this should match closely with the *total achieved curriculum* to reflect the achievement of students as fully as possible. In any case, it will feed back to the *working curriculum* so that planning of teaching and learning activities can be modified accordingly.

The curriculum framework highlights the important interfaces in the curriculum process to which the curriculum evaluator should pay attention. Based on this framework, I constructed the evaluation framework as described in the next section.

4.2.3 The evaluation framework

As indicated by the review in Chapter 3, an evaluation can be made more "illuminative", by targeting all the three levels of curriculum such that the information elicited at one level could inform the other two. Hence, in the present evaluation, I focus not only on the achieved outcomes, but also on the intrinsic qualities of the intended curriculum, and the teaching practices. This means that I can construct my evaluation framework by super-imposing my research questions onto the appropriate levels of the curriculum framework. Fig. 4.2 illustrates the evaluation framework.

Level / sub-levels of curriculum	Research questions / sub-questions
Intended curriculum Conceived curriculum Documented curriculum Textbook curriculum	RQ1: What is the context of the reform and what makes the new curriculum distinctive from the previous curriculum? • What are the context of the reform, and the principles and theoretical underpinnings conceived by curriculum planners as important to guide the development of the new curriculum? (1.1) • How did curriculum planners translate their perceptions of reform into the official curriculum document? (1.2) • What similarities and differences between the new and old curricula are apparent? (1.3)
Implemented curriculum Teachers' perceived curriculum Working curriculum Practiced curriculum	RQ2: Do teachers implement the new curriculum as intended by curriculum planners, particularly with respect to the use of the investigative approach? • How do teachers perceive the new curriculum? To what extent are teachers' perceptions in line with the intended curriculum? (2.1) • How does the working/practised curriculum differ from the teachers' perceived curriculum? (2.2) • What opportunities and constraints are present? How do these opportunities and constraints affect implementation? (2.3)
Achieved curriculum Total achieved curriculum Measured achieved Curriculum	RQ3: Is there any evidence of improvement in students' process skills and attitudes toward science on completion of the first year when compared with the old curriculum? To what extent is the science self-concept of students influenced by the new curriculum? • How do students' process skills, attitudes towards science and science curriculum, and science self-concepts change in the first year of the implemented curriculum? (3.1) • How does the new curriculum compare with the old in terms of students' achievements measured by the parameters mentioned in Sub-question 3(a)? (3.2)
	RQ4: What are the implications of the research findings for the continued implementation of the new curriculum?

Figure 4.2: The evaluation framework

In the paragraphs that follow, I elaborate how the research questions indicated in this framework guide the evaluation of the new curriculum.

RQ1 addresses the intended curriculum. In more specific terms, it sets out to reveal the *conceived* curriculum including the context for the reform and the rationale or vision behind the planners (Sub-question 1.1). This takes into account the driving forces behind the reform and conceived by the planners, which proves to be important in catalyzing reforms as discussed in Chapter 2. It then focuses on the consistency between the planners' perceptions and the official syllabus (Sub-question 1.2). The inquiry of the *conceived* and *documented* curriculum will be approached from a comparative perspective to identify the differences between the new and old curricula (Sub-question 1.3). This part of evaluation draws largely on the strategy of intrinsic evaluation as reviewed in Section 3.2.2 (p.78). This allows inquiry into the internal consistency between aims, content and teaching approaches. This also paves the way for analyzing the congruence between the intended and implemented curriculum. The notions of consistency and congruence are based on Stake's Countenance model (Section 3.2.2, p.79). Nevertheless, I have no intention of judging the desirability of the curriculum intentions, nor will I attempt to refute the theoretical positions or beliefs of the curriculum planners. I only play the role of a critical evaluator, providing analysis of what is happening and identifying any inconsistencies within the sub-levels and at their interfaces, which have implications for implementation and generation of outcomes.

The *textbook* curriculum is not a particular focus for this study for two main reasons. First, it is assumed that the textbooks must meet the basic requirements of the documented curriculum, otherwise they would not be recommended by the CDI. Second, there are about ten textbooks available for use by Hong Kong schools. Given my limitations as a lone researcher, analysing all these implies sacrificing other parts of the study. Hence I decided to leave this to another study. Oakes and Carey (1989) point out that, in practice, an evaluator has to select particular domains and methods. Even in an elaborate evaluation, compromise is required about the aspects that can be included. Nevertheless, the influence of the textbook is likely to surface when the consistency between the *documented* and the *teachers' perceived/working* curriculum is analyzed. If a significant incongruence is observed, this could be due to the influence of the textbook.

RQ2 elucidates the implemented curriculum. Sub-question 2.1 explores the *perceived* curriculum, basing on the premise that teachers will perceive the characteristics of the new curriculum before they could adjust their teaching accordingly. However, as discussed in Section 2.4.2, even though teachers are able to perceive the reform as desired by the planners, they do not necessarily plan their teaching consistently with their perceptions (Hodson 1998). Hence, it would be necessary to check the consistency between the *perceived* and *working/practiced* curriculum of teachers (Sub-question 2.2). Sub-question 2.3 explores the opportunities perceived and constraints encountered by teachers in translating the *perceived* curriculum to the *working* and the *practised* curriculum. Although the *working* and *practised* curriculum are clearly differentiated in this framework as two separate sub-levels, it will be difficult to distinguish them in practice without undertaking a detailed discourse analysis. Hence they are combined in this part of the study. This part of evaluation is in line with the "process" evaluation in the CIPP model (Section 3.2.2, p.83) or the "observed transaction" in Stake's Countenance Model.

The achieved curriculum is explored as guided by RQ3. Science process skills, attitude toward science and the science curriculum, and science self-concept are chosen as assessment criteria. The rationale of this choice will be detailed in the latter part of this chapter. Again, comparative evaluation will be utilized to identify any evidence of improvement of student outcomes under the new curriculum (Sub-question 3.2).

Based on the findings to the first three research questions, the implications of the outcomes of the present study for the future implementation of the new curriculum will be analyzed. This echoes Cronbach's view that evaluation should enable the course developer to do a better job and to understand more deeply the educational process (Section 3.2.1, p.76). This forms the focus of RQ4.

4.2.4 Ethical stance as an evaluator

As reflected in the literature review in Chapter 3, one of the factors influencing the evaluation outcomes is the evaluators' hidden assumptions about the value of the curriculum. These assumptions may introduce bias in data analysis and the drawing of conclusions. Thus the evaluator should be aware of his or her own assumptions. As a former secondary science teacher, I am aware of the Hong Kong's school and classroom contexts, and the constraints to curriculum implementation. This may lead to preconceptions of the context while analyzing the intended curriculum and factors affecting its outcomes. Being a teacher educator now allows me to stand back and view the classroom situation in a more objective manner. However, being impartial and objective does not mean that the evaluator needs to be indifferent to what happens around him. The evaluator has to possess empathy in order to fully understand and appreciate the subject's perceptions and feelings.

4.3 Strategies and methods of evaluation

4.3.1 Rationale for the methodological design

As guided by the evaluation framework, the study collects data from the three curriculum levels and its sub-levels. In Section 3.3.5 (p.108), I have argued that a multi-method approach based on both positivistic and interpretive paradigms would be most ideal for data collection at the three levels of curriculum. This allows me to capitalize on the strengths of the two research paradigms to make the evaluation an "illuminative" one. Thus, I draw on, first, the "Social Anthropology" model for devising methods to elicit the views of different stakeholders including curriculum planners, teachers and students; second, the "Agricultural Botany" model for comparing students' performance in the old and new curricula; and, third, the "Adversary" model to analyse the strengths and weaknesses of the new curriculum from both a supportive and a negative point of view. This integrated approach, which necessitates the collection of both quantitative and qualitative data from various sources, is supported by Lawrenz and McCreath (1988). As argued by the two researchers, the "qualitative components provide richness to the data and are a valuable source for identifying potentially relevant variables" while the "quantitative components provide the 'hard data' necessary to document the degree of the effects" (p.406). This type of data collection method also allows triangulation of data, thereby enhancing reliability and validity (Rossman and Wilson 1984).

I outline my methodology by setting out a time-line to show the sequence and relationship of all the major events planned for each of the three levels (Figure 4.3).

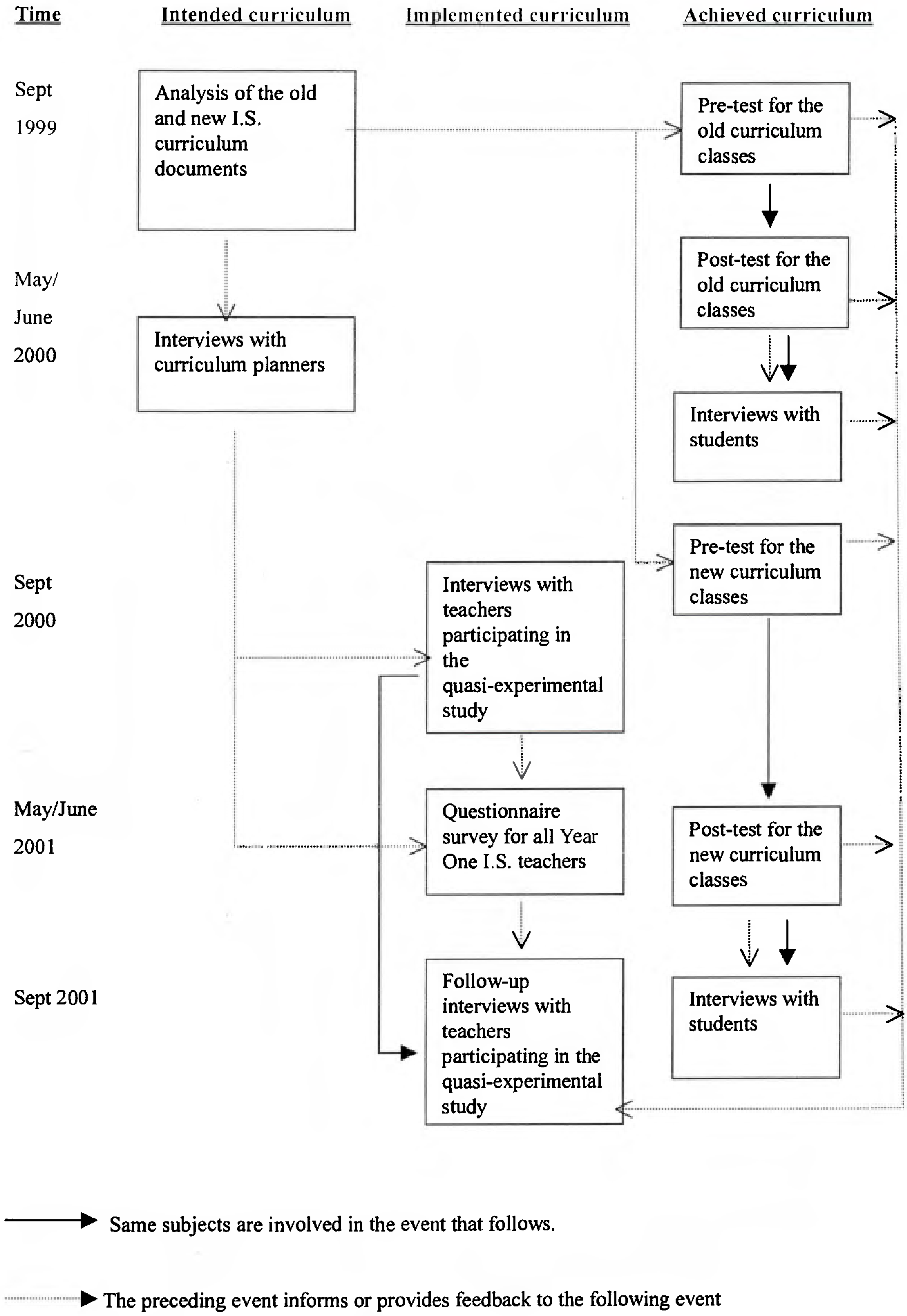

Figure 4.3: Time-line showing the data collection methods for the three levels of curriculum

4.3.2 Answering the research questions

As indicated by the time-line, both qualitative and quantitative methods were employed which pitched at the three curriculum levels. As for RQ1, the curriculum planners were interviewed to identify the context of the reform and the distinctive features of the new curriculum. The syllabus was also analyzed to understand how the planners' intentions were translated into written guidelines for practice. RQ2 was answered based on data collected through teacher interviews and questionnaire survey, and, to a lesser extent, by student interviews. These methods helped to ascertain whether teachers perceived and implemented the new curriculum in the way as intended by curriculum planners. RQ 3 was mainly answered by a quasi-experimental study designed to measure changes in student learning outcomes, supplemented with qualitative data obtained from student interviews, which also provides corroborating evidence for the implemented practices. Finally, the implications of the findings from the three curriculum levels were analyzed and developed to provide an answer to the final research question.

The following sections explain in detail the strategies employed at each level, including the methods, sampling procedures and pilot tests, as well as reliability and validity issues.

4.4 The intended curriculum

4.4.1 Evaluation strategies

As discussed in Chapter 2, curriculum development in Hong Kong follows a center-periphery approach. The Science Subject Committee of the CDI engineered the whole reform process. Interviews with curriculum planners in the Committee was considered as the most appropriate method for eliciting first hand information about the context of reform, and the initiation and planning process, thus casting light on the conceived curriculum. To gain a full understanding of the documented curriculum, the syllabus was subject to intrinsic analysis. The findings obtained by these two methods were synthesized to achieve an overall understanding of the intended curriculum.

4.4.2 Curriculum planner interviews

The interviewees were drawn from the Science Subject Committee of the CDI. Membership of the Committee comprises both government and non-government members. The senior curriculum planner and a representative from a teacher training college were selected as subjects. The former had played a key role in engineering the whole reform process and was the best resource person to illuminate the conceived curriculum. The latter was chosen in the light of her independent status, as she was neither a government official nor a schoolteacher involving directly in the implementation of the curriculum.

Semi-structured interviews were conducted to obtain a retrospective account of the process from the planners. This enabled the interviewees to address important questions while allowing them to diverge to other issues they felt important. The interview protocol is provided in Appendix 4.1. The questions were focused primarily on the factors behind the curriculum reform and the distinctive features of the new curriculum as perceived by the interviewees. Their perceptions of problems influencing implementation were also solicited to understand how these problems were overcome, and how far they had influenced the enactment of the documented curriculum.

As requested by the Senior Curriculum Development Officer, a formal letter was sent to seek permission for conducting the interview (Appendix 4.2). The interviews were conducted in Chinese. All the interviews were taped recorded with the permission of the interviewees. The taped records were transcribed and translated to English before sending to the interviewees for validation. Permission was obtained from all interviewees for citing them in the thesis as and when appropriate.

4.4.3 Documentary analysis

Strategies for analysis

The approach to analysis was based on comparative and intrinsic evaluation (Scriven 1967). The framework for the documentary analysis of the new curriculum is provided in Appendix 4.3. The focus of the analysis was two-fold. First, the different levels of specifications of the syllabus, including the aims, objectives, suggested teaching strategies and approaches, the topics and their contents, suggested teaching and learning activities, and suggested modes of assessment, were compared with that of the old curriculum. This was to illuminate features that distinguish the new curriculum from the old one. Second, the consistencies between aims, content and teaching approaches of the new curriculum were evaluated. This aspect of analysis would provide evidence about the degree to which the aims were translated into intended teaching practices.

Because of the specificity of the analysis, it was difficult to adopt the methods of analysis of other studies. To fit in with the design and organization of the syllabus, the following methods were used. The aims and objectives of both curricula were categorized into the same broad themes according to their similarities. Any characteristics unique to either one of the curricula were treated as separate themes. An item-to-item comparison was then made under each theme to identify the characteristics of and compare the differences between the two curricula.

At the content level, the topic areas of two curricula were compared unit by unit, highlighting the addition and deletion of topic areas in the new curriculum as compared with the old one. The teaching and learning activities were analysed by two procedures. The first was to check the consistency between the objectives and the teaching activities in the new curriculum. In the new syllabus, each of the practical and learning activities is matched to a skill. Appendix 4.4 shows a sample unit of the syllabus with a list of suggested activities and the corresponding skills. In order to identify to what degree the objectives are covered by these activities, each activity was matched to the objectives as listed in the syllabus. The procedure was to assign a code to each objective, e.g. K1-3 for the objectives under "knowledge and understanding" etc. (see Table 5.3, p.175). Matching was done by my personal judgment based on the activity descriptions, and the skills ascribed to them by the planners. The objectives matched to an activity were recorded by entering their corresponding codes against the activity. Appendix 4.5 shows an extract of the syllabus to show how the matching was done.

The second procedure was to analyze the suggested activities based on their teaching strategies or approaches. The teaching approaches were mainly inferred from the instructional phrases used by the planners to describe the activities. Both procedures were applied to the old and new curricula to facilitate comparison between the two.

Issues of reliability and validity

To ensure validity, triangulation of data from different sources was employed.

The three types of triangulation identified by Denzin (1978): "methodological", "data" and "investigator" were utilized. For methodological triangulation, both interviews and curriculum analysis were used to elicit the expressed and hidden information about the intended curriculum. Data triangulation was achieved by obtaining information separately from both government and non-government curriculum planners. Investigator triangulation was applied to validate parts of the curriculum analysis that necessitated subjective judgments. This was achieved by inviting academics in this field to validate my findings. The full methodological framework were also made as explicitly as possible in this thesis, thereby fulfilling the validation principle for curriculum criticism (Werner 1980). Furthermore, the interview transcriptions were sent to the planners for validation and for further supplement as they thought appropriate. This fulfils the requirement suggested by Janesick (1994) and Lincoln and Guba (1985) that the researcher should find a way to allow the participants to review the material.

4.5 The implemented curriculum

4.5.1 Evaluation strategies

The aim of this level is to evaluate the implementation of the curriculum in the classroom. This investigates how teachers perceived the intended curriculum and the extent to which teachers complied with or adapted to it. Alternative strategies had been considered, including direct methods like classroom observation and less direct ones like interviews and surveys. Classroom observation seemed to be promising in collecting direct evidence of what happens in the classroom. However, this method is neither feasible nor valid in the present context for two reasons. First, since the study spans two years, a relatively large number of class observations would be needed to obtain data that represented teachers' practices. However, this would not be feasible for part-time researchers like myself engaging in full-time teaching duties. The second reason is that the culture of classroom observation has yet to be developed in Hong Kong secondary schools, not to mention doing this regularly for a substantially long period of time. Classroom teaching is still very much the "private" affair of the teacher, so classroom observation may create uneasiness or over-preparation, thus threatening the validity of the data. From a more pragmatic viewpoint, this method may also deter teachers from participating in the study saving for the very enthusiastic ones.

Hence, I decided to employ an indirect strategy, which encompassed mainly two methods: a large-scale questionnaire survey of all Secondary 1 science teachers and interviews with a selected group of teachers. While the questionnaire elicited an overall picture regarding the state of curriculum implementation, the interviews collected more in-depth views about the curriculum and factors underlying their pedagogical choices, hence reflecting teachers' perceived and working/practiced curricula.

Apart from the teacher questionnaire survey and interviews, interviews with students were also conducted to elicit their views about the implemented curriculum. Since the prime purpose of these interviews were to gain a more thorough understanding of the achieved curriculum, details of the design of the student interviews will be described in Section 4.6.8 (p.150).

4.5.2 Teacher interviews

Four Year One I.S. teachers were selected for interviews. They were selected as they were participating in the quasi-experimental study which gauged student outcomes. Hence, the data obtained from the interviewees can be related to their student outcomes. The method of sampling of schools and teachers for the quasi-experimental study is described in Section 4.6.3 (p.138)..

The teachers were interviewed twice individually. The first interview took place in March, 2001 when they were about half way through the curriculum. This interview focused on teachers' perceptions about the intended curriculum, perceived classroom practices, and their impact on student motivation and learning behaviours. The second interview took place when the academic year was over. The aim was to elicit interviewees' reflections on their own experiences in the past year and their suggestions for changes in future practice. This helped to gauge their attitudinal and behavioral change during the implementation process. The interviewees were also invited to account for the performance of their students in the quasi-experimental study based on their own reflections on the intended curriculum and on their teaching practices. This is in line with Fullan and Pomfret's (1977)'s argument that implementation studies are important because they help to interpret learning outcomes and to relate them to possible determinants.

The interview protocols for the two rounds of teacher interviews can be found in Appendix 4.6. A pilot interview was conducted with an I.S. teacher to ensure that the questions used in the first interview were properly worded and not likely to be misunderstood. Results show that only minor amendments were necessary. All interviews were audio taped with the consent of the interviewees. The taped records were transcribed and translated to English before validating by the interviewees. The interviewees were welcomed to elaborate on the points they made if they thought this helped to clarify what they said. Pilot interviews were considered unnecessary for the second round of interviews based on the first round experience.

4.5.3 Teacher questionnaire

The sample

A questionnaire was sent to all teachers teaching Secondary 1 science in local secondary schools. Teachers of Secondary 2 and 3 were excluded because most schools implemented the new curriculum only in Secondary One to avoid abrupt changes. Since teachers returned the questionnaire on a voluntary basis, so the effective sample included only those making a response.

The design

The aims of the questionnaire were to elicit teachers' perceived curriculum and their actual practices in the classroom, i.e. their working/practised curriculum, particularly regarding the teaching of scientific investigations, which is central to the new curriculum framework. The survey also aims to reflect from the teachers' perspective the likelihood that the new curriculum would fulfill its goals. Based on these aims, five measures of perceptions and implementation were built into the questionnaire. They are listed as follows:-

1. *Teachers' perceived curriculum*
   - *Sources of knowledge about the new curriculum*
   - *Differences between the new and the old curricula*
   - *Distinctive characteristics of the new curriculum*
2. *Teachers' working/practised curriculum*
   - *Degree of change in teaching practices*
   - *Implementation of investigative activities*
3. *Perceived Constraints in implementing the new curriculum*
4. *Teachers' preparation and resources support*
   - *Perceived adequacy of one's own preparation in teaching the new*

curriculum

- *Self-confidence in implementing investigative activities*
- *Perceived training needs*
- *Perceived resources support required*

5. *Teachers' evaluation of the new curriculum*
   - *Perceived chance of fulfilling the goals compared with the old curriculum*
   - *Perceived level of satisfaction with major curriculum areas*
   - *Most valued aspects of the curriculum*
   - *Perceived student motivation and attitudes toward the curriculum*
   - *Overall perception of improvement of the new curriculum over the old curriculum*

The pilot test

A trial questionnaire was developed (Appendix 4.7) and pilot-tested with 10 I.S. teachers of Year One. The questions took different forms including rating scale, checklist ranking type, and open questions. The design was to facilitate respondents to explore, recollect and express their perceptions, views and actual practices in a way that is as natural and non-intimidating as possible. Two experts in science curriculum in my institution had reviewed it to ensure its face and content validity. The pilot questionnaire was translated into Chinese as almost all teachers targeted are Chinese-speaking. From the findings of the pilot test and experts' review, some changes were made, which were incorporated into the final version of the questionnaire (Appendix 4.8). These changes are described as follows. (The question numbers used are those of the pilot test, unless stated otherwise.)

Questions that were deleted entirely:

Q.13 and Q.14 -- Their meanings are vague, and they serve similar purpose as Q9 and 15.

Questions that were amended: *(The numbers in bracket and italics indicate the question numbers of the amended questions in the final version.)*

Q.8 *(9)* - To avoid respondents checking "not sure", which did occur rather frequently in the pilot test, this option was removed to "force" respondents to come up with their own standpoints. At the same time, two more options: "Agree strongly" and Disagree strongly" were added. These changes should help to arrive at a better understanding of teachers' perceptions about the difference between the new and the old curriculum

Q11 *(11)*, 12*(13)*, 15*(14)*, 24*(23)*, and 26*(25)* – *A*part from asking respondents to check from a list of options, they were asked to rank the options according to the importance to them. This change could yield further information without the addition of further questions.

Q.15 (*14*) – One additional reason "Building up self confidence and assurance of one's ability" was added to the list to reflect one of the intentions behind the reform as suggested by the curriculum planners during the interviews.

Q19 *(17)* - *A*part from completing the scale, respondents were also asked to provide reasons for their choice. This is because without this, it is impossible to understand the respondents' choice. For similar reasons, an explanation of the respondent's answer is also required for Q.22*(21)*.

Q.21 (*20*) – The aim (f) was added to reflect the achievement of the aim concerning the acquisition of decision-making skills.

Questions that were added:

Q.6 – This could reflect the preparation of teachers as well as their depth of understanding about the new curriculum.

Q.27 – This reflects respondents' perception of their own adequacy in preparation.

In addition, the sequence of some of the questions was rearranged to improve the "flow", facilitating the ease of answering.

The administration procedure

The revised version of the questionnaire was translated into Chinese (Appendix 4.9), which was checked by a Chinese-English translation expert to ensure its accuracy. Since the number of I.S. teachers teaching in Year One would normally not exceed three in each school, three questionnaires were sent to each school. The questionnaires were addressed to the science panel head under a covering letter, explaining the aims of the questionnaire survey and soliciting their help in distributing the questionnaire. To facilitate the return of questionnaire and to enhance the response rate, each questionnaire was attached with a stamped and self-addressed return envelope. This also ensures confidentiality of the respondents.

4.5.4 Validity of the methods

Since both questionnaires and interviews relied on respondents' self-reporting as a means for collecting data, they were subject to problems of invalidity (Cohen and Manion 1994). The main issue is that there may be incongruence between what the teacher said and what he or she actually behaved in the classroom. Besides, there were issues like whether the questionnaire or the interview protocol could serve as a valid instrument for eliciting the kinds of information that they are expected to find out. To ensure validity and reliability of data, several measures were taken.

Since the questionnaire was not concerned with specific psychological constructs, but rather with the elicitation of perceptions and behaviours, content validity is the most important type of validity to be established (Cone and Foster 1993). This was achieved through experts' review of the questionnaire and the interview protocol. To ensure congruence between what teachers say and do. Three measures were built into the questionnaire design and administration. First, teachers' responses to the questionnaire were entirely voluntary, hence the likelihood of intentional false reporting was reduced to a minimum. Despite this, teachers might report false information unintentionally, for example, when their memory fails them.

As a second precaution, some questions were stated very specifically with the necessary information provided to help respondents recapitulate what they had done. In Q.10, for example, a list of investigative activities was provided for respondents to determine how many they have covered in their classes. Third, some questions were designed to be open ones to elicit respondents' general or specific perceptions and feelings. Examples of these questions are:

- *What features of the new curriculum do they value most?*
- *What are the obstacles to the effective implementation of the curriculum?*

These open questions allowed teachers to explore their thoughts and feelings, while keeping the option open to leave questions blank instead of coming up with some invalid answers. Furthermore, the coupling of in-depth interviews with a wide-scale questionnaire survey facilitated data and method triangulation. Data obtained from student interviews could also triangulate with the findings of the teacher interviews.

4.6 The achieved curriculum

4.6.1 Evaluation strategies

Data collected on the achieved curriculum should help to ascertain the extent to which the curriculum intentions were achieved. However, as argued by Campbell et al (1994) in evaluating Salters' Chemistry (Section 3.3.2, p.100), it is difficult to associate individual observed outcomes of a long course with specific features of its approach or design. Hence, this necessitates selection of evaluation criteria from the wide range of curricular objectives stated in the Syllabus.

As informed by preliminary analysis of the syllabus, the new curriculum is distinctive in its emphases on investigation and its requisite science process skills, as well as on the relevance of science to society or students' daily lives. To reflect these two emphases, two parameters were chosen as indicators of student outcomes: the ability of students to utilize a suitable range of process skills in carrying out investigations, and students' attitudes toward science. The latter parameter were selected because if the new curriculum is an effective means for students to learn science including its processes and relevance to society, there is a good reason to believe that students' attitudes toward science should become more positive. Research had shown that certain instructional strategies such as field-based science methods (Story and Brown 1979), laboratory-oriented science curriculum methods (Milson 1979; Freedman 1997), and a combination of laboratory approach and lecture (Saunders and Dickinson 1979) had positive influences on students' attitudes toward science.

Apart from process skills and attitudes toward science, two additional criteria were used for measuring student outcomes: students' attitude toward the science curriculum, and science self-concept. Although these two attributes are not explicitly related to the aims, they could provide strong supplementary evidence to indicate the effectiveness of the new curriculum. This is because if the new science curriculum is effective, students should find it interesting and inspiring, hence developing a more positive attitude toward it. Likewise, if the curriculum could enhance and empower students' learning in science, it shall promote their science self-concept, i.e. their perceived ability of learning science.

Researchers had argued that self-concept is an important indicator of program effectiveness, providing a more holistic assessment outcome. However, whether it is a precursor or result of success may vary from individual to individual (Peterson, Kauchak et al. 1980). Krockover and Malcolm (1977) found that a new curriculum encouraging creative, innovative and independent thinking could help to elevate certain aspects of students' self-concept Evidence also suggests the importance of self-concept in predicting whether students would continue in science. DeBoer (1984) found that a sense of competence was important to successful college freshman to continue studying science. Jacobowitz (1983) demonstrated that science self-concept was significantly related to black junior high school students' science career preference.

In this study, content knowledge was not assessed. This is because given the diverse content, it is difficult to construct a valid instrument for measurement. Moreover, the content knowledge is much more context-specific than the other four criteria to be measured, making valid comparison between the new and the old curricula difficult.

With the evaluation criteria chosen, the next concern was how to make sense of the measured outcomes, that is, how to judge whether the outcomes are better, the same or even worse than those of the old curriculum. To identify improvement resulting from the new curriculum, it is necessary to compare students' achievement with the old one. A true experimental design involving random assignment of students into two curriculum groups would be an ideal strategy. However, this is not feasible because the new curriculum was meant to replace the old one completely, therefore the two did not co-exist. Hence, a quasi-experimental approach involving intact classes was used instead. Details of the design are provided in the next section.

To further illuminate the findings of the quasi-experimental study, semi-structured interviews were conducted with a small sample of students. These were used as a focal point to elicit students' feedback on their own performance, on the curriculum, and on the teaching and learning practices occurring in the classroom. The findings also helped to triangulate data obtained from the teacher interviews. Details of the student interviews are provided in Sub-section 4.6.8 (p.150).

4.6.2 The quasi-experimental design

The quasi-experimental design was based on a non-equivalent control group design (Cohen and Manion 1994) with two curriculum groups, each being made up of intact classes. As the new curriculum completely replaced the old one starting from the academic year of 2000/2001, the old curriculum group was drawn from the Secondary One cohort in 1999/2000, i.e. the last cohort following the old curriculum, and the new curriculum group from the 2000/2001 cohort, the first cohort to study the new curriculum.

Students in each of the two curriculum groups were given a pre- and a post-test using standardized instruments for assessing attitudes toward science, attitudes toward science curriculum, science self-concept and process skills. This allowed the gain in score by different curriculum groups to be measured, hence helping to establish the relative merits of the two curricula. Details of the instruments used are described in Section 4.6.5 (p.143). The pre-test was administered at the beginning of the school year, and the post-test towards the end. Since both tests used the same instruments, in order to take into account possible sensitizing effects of the pre-test, each curriculum group was further divided into two sub-groups. One sub-group took both pre- and post-test while the other sub-group took the post-test only. Hence, any impact of the pre-test could be identified by comparing the gain in score by the two sub-groups in the post-test. Such impact, if any, would be taken into consideration when analyzing the results. Figure 4.4 summarizes the design adopted for the present study.

Old curriculum group:			
Pre-tested subgroup (old):	Pre-test -------	Old curriculum --------	Post-test
Non-pre-tested subgroup (old):		Old curriculum -------	Post-test
New curriculum group:			
Pre-tested subgroup (new):	Pre-test-------	New curriculum -------	Post-test
Non-pre-tested subgroup (new):		New curriculum -------	Post-test

Figure 4.4: Overall design of the quasi-experimental study

4.6.3 Sampling for the quasi-experimental study

The small school sample has to be small due to my limitation as a lone evaluator. Thus, random sampling may not be appropriate because this may lead to greater bias than the case when the sample size is large. Hence, schools were chosen through purposive sampling, which Popham (1993) characterizes as "an attempt to secure a representative sample by deliberately selecting groups thought to be typical of the population. Popham further argues that "if, employing real-world wisdom, evaluators can use samples that are as representative as possible, this approach will usually be sufficient for the needs of most decision makers" (p.248). In line with this argument, seven schools were chosen purposely according to the following criteria:-

a) *The school is using Chinese as the medium of instruction.*
b) *The student intake normally falls within the average ability range.*
c) *The school is located in public housing estates.*
d) *The school does not belong to the network of schools that participates in the*

Curriculum Tailoring Scheme organized by the Curriculum Development Institute or undertaking any school-based development project with the CDI on I.S.

e) *The school head can be accessible through some "contact person" so that there is a greater chance of acceptance.*

The reasons for not choosing schools using English as the medium of instruction were that the student intake to these schools is generally of higher ability, and that they represent only about a quarter of secondary schools in Hong Kong. Schools were also chosen from those located in public housing estates which are typical of most schools in Hong Kong. This also ensures that students were from more or less the same socio-economic background. Schools involving in the Curriculum Tailoring Scheme, a voluntary scheme for enhancing school-based curriculum development to cater for the needs of lower ability students, were excluded. This is because in such cases, the content and approaches may be modified to a fairly great extent. With these restrictions in sampling, the effective school population under study was reduced. Hence, the present quasi-experimental study could only make claims on student outcomes in CMI schools with students of average abilities.

The adoption of the fifth criterion was due to pragmatic reasons. It would be difficult to obtain the support of school heads to engage in an individual study of this kind, which demands a heavy commitment in terms of teacher time and effort. Hence, invitations were extended only to target schools that were "accessible" through either direct or indirect personal contacts. The teachers were provided with detailed information about the research design to make sure that they were fully aware of the commitment required. This facilitated smooth cooperation during the study as well as minimizing the chance of teachers dropping out due to misunderstanding of the requirements. Of the seven schools invited, five including six teachers and eight classes were recruited successfully for the first year of the study.

As foreseeable, when the study proceeded from the first year to the second, some teachers dropped out from the study. This was because they were no longer assigned to teach Year One classes. In consequence, the class sample of the new curriculum group dropped from eight to five. I made no attempt to select another three classes from those schools to compensate for the loss of samples. The reason was that such a change would introduce new teachers to the new curriculum group, hence introducing extraneous variables to the study. The number of classes in the two curriculum groups were equalized by removing three classes from the old curriculum group. Details are described in Section 7.2.1 (p.238). The number of class teachers involved in the school samples of the two curriculum groups are provided in Table 4.1.

School	No. of classes	No. of teachers	No. of students
1	1(1)	1(1)	39(40)
2	2(1)	1(1)	77(41)
3	2(2)	1(1)	80(83)
4	2(1)	2(1)	79(43)
5	1(0)	1(0)	36 (0)
Total	8(5)	6(4)	311(207)

The numbers not within parentheses belong to the old curriculum group. Those within parentheses belong to the new curriculum group.

Table 4.1: Details of the samples in the two curriculum groups

To assign students into pre-tested and non-pre-tested sub-groups, a method short of random sampling was adopted. Students with odd numbers in their class register entered the pre-test group; and those with even numbers entered the other sub-group. This procedure avoided causing confusion to both teachers and students. Since it is the usual practice of Hong Kong schools to sequence students within a class according to the alphabetical order of their family names, this method should not introduce any bias to the composition of the two sub-groups, including bias in gender or ability of students.

4.6.4 Validity of the design

As in all experimental designs or quasi-experimental design, the present design is subject to threats to both external and internal validity (Cohen and Manion 1994). As for external validity, it was necessary to safeguard against the Hawthorne effect, that is, the awareness of participation by the subjects in an experiment may affect their performance (Bracht and Glass 1968). However, the Hawthorne effect was unlikely to exert a substantial impact in this case because I did not mention to the teachers what outcomes were expected from the comparison. Also, because of the long time span and the absence of interference by the evaluator through class observations between the pre- and post-tests, it was unlikely that the teachers would be significantly influenced by the experiment.

The second possible threat was that the teachers might devote more time in preparing for the teaching because of enhanced enthusiasm towards a new curriculum although the magnitude would depend on individual teachers. This effect could be detected to a certain extent through the teacher interviews. Third, the teachers might lack in faith toward a new curriculum or might not have acquired sufficient content or pedagogical knowledge, hence resulting in a less satisfactory outcome. However, this should not be considered as a threat since one of the aims of this research is to identify factors that are likely to influence the curriculum reform process. The novelty of the curriculum to teachers could be one of them. From the results of the teacher interview and questionnaire survey, I will try to differentiate long lasting constraints from transient ones.

The fourth threat to external validity is pre-test sensitization (Bracht and Glass 1968). Pre-test results may interact with curriculum effects, thereby affecting the outcomes of the post-tests. For instance, students who did the pre-test might work better in the post-test either because they were familiarized with the test items and format, or because they became more attentive to that part in their classes. Nevertheless, as mentioned in the previous sub-section, this effect could be detected and controlled for using a four-group design. By comparing the results with those of the corresponding non-pre-test sub-groups, any favour toward the pre-tested sub-groups could be identified.

As for internal validity, most of the threats could be offset by adopting a four-group design. These threats include maturation effects of students and statistical regression. Although the study was affected by experimental mortality as described in Section 4.6.3, it would not affect the results because the mortality is not a form of differential attrition, that is, attrition that results in bias within the remaining sample. Non-random assignment of subjects into the two curriculum groups might pose the most significant threat to internal validity. For instance, students in the two groups may vary in academic abilities, as well as other demographic characteristics, making cross comparison problematic. In this study, I minimized this threat by three means. The first was by matching the ability of corresponding classes in the two curriculum groups based on the pre-test results. However, this could only be done to a limited extent because there is little freedom in selecting classes from either cohorts. These classes were "dictated" by teachers who were willing to participate in this study. Second, I controlled the teacher factor by assigning classes taught by the same teacher to different curriculum groups. Third, the variability between the two curriculum groups were controlled by statistical means as far as possible. Covariance techniques were used to adjust variation between the two groups, using pre-test results as the covariate.

4.6.5 Instruments for measuring student outcomes

Four standardized instruments were used to measure the four outcome indicators: students' attitude toward science, attitude toward science curriculum, science self-concepts and science process skills. These standardized instruments were either directly adopted or adapted with slight modifications from previous research studies because of their immediate relevance in terms of content, and their proven psychometric properties. I will describe each of these instruments in turn.

Attitude toward science scale

This scale was adapted from the Attitude toward Science Sub-scale developed by (Simpson and Troost 1982). The full scale developed by the two authors also included sub-scales to measure attitude toward science curriculum, motivation to achieve in science, science anxiety and attitude toward science teacher. The original Attitude toward Science Sub-scale consists of seven items:-

1. *Science is fun.*
2. *I have good feelings toward science.*
3. *I enjoy science courses.*
4. *I really like science.*
5. *I would enjoy being a scientist.*
6. *I think scientists are neat people.*
7. *Everyone should learn about science.*

Respondents were asked to indicate their agreement to the above items on a five-point Likert scale, ranging from "strongly agree" to "strongly disagree" with "not sure" in between. When used in its original form, Cronbach's alpha reliability estimate is 0.88, indicating a very high internal consistency.

In the trial of the translated instrument (see Section 4.6.7, p.149), the above scale was slightly adapted. Item 4 was amended as "Science is boring". This was partly because in Chinese the original item "I really like science" has a very similar meaning to Item 2. The reason for adding a negatively worded item is to increase the alertness of the respondents in answering the questions. Apart from this amendment, two new items were added to the original scale. The first one "Learning science helps me to cope with the world" reflects the social relevance of the new curriculum and serves as a complement to Item 7. The second item "Science is too technical" was added to reflect a common negative feeling about science, and it is worthwhile to find out whether the new curriculum could help dispel this. However, this latter item were removed from the scale after pilot testing because of its negative effect on the internal consistency of the scale. The revised scale in the main study is:

1. *Science is fun.*
2. *I have good feelings toward science.*
3. *I enjoy science courses.*
4. *Science is boring.*
5. *I would enjoy being a scientist.*
6. *I think scientists are neat people.*
7. *Everyone should learn about science.*
8. *"Learning science helps me to cope with the world"*

Attitude toward science curriculum scale

This scale was adopted from the Attitude toward Science Curriculum Sub-scale of the Simpson's and Troost's scale(Simpson and Troost 1982; Talton and Simpson 1986). When used in its original form, Cronbach's alpha reliability estimate was reported to be 0.71. It is used in the present study to elicit feedback on both the new and old curricula. The original scale consisting of 4 items on a 5-point Likert scale was adopted without change:-

1. *We do a lot of fun activities in science class.*
2. *We learn about important things in science class.*
3. *We cover interesting topics in science class.*
4. *I like our science textbook.*

Science self-concept scale

Science self-concept was measured by a scale adopted from the science sub-scale of the ASDQ-II instrument developed by Marsh (1990) (Marsh 1990)for assessing the science self-concept of grades 7-10. The coefficient alpha estimate, as used in its original version is reported to be within the range of 0.885 to 0.949, indicating a very high internal consistency. This scale comprises six items:-

1. *Compared to others my age I am good at science.*
2. *I get good marks in science.*
3. *Work in science classes is easy for me.*
4. *I am hopeless when it comes to science.*
5. *I learn things quickly in science.*
6. *I have always done well in science.*

In the original version of this instrument, students will select one of the six response categories in responding to each item: false; mostly false; more false than true; more true than false; mostly true; and true. In order to make this consistent with the two other sub-scales to avoid confusion to students, the six response categories in the Science Self-concept sub-scale were reduced to five using wording identical to the other sub-scales. All three sub-scales were translated to Chinese, which was validated by an English-Chinese translator. The trial and final versions in both Chinese and English are in Appendix 4.10 and 4.11.

Performance in science process skills

Students' performance in science process skills was assessed by both paper-and-pencil test (both MC and free-response types) and performance assessments drawn from the released items set used in TIMSS (Harmon, Smith et al. 1997). The reasons why TIMSS items were chosen as the instrument for assessing students' science process skills are that, firstly, they were well validated and thoroughly tested. Secondly, the process skills assessed by TIMSS match very closely those emphasized in the new curriculum (HKCDC 1998), thus ensuring content validity. Thirdly, TIMSS had been administered in Hong Kong and the test items had been translated into Chinese for ready use. As I had assisted in the administration and scoring of the performance assessment tasks at that time, my experience should be helpful to ensure the reliability of the tests used in the present context. The items used in this study consisted of seven paper-and-pencil test items and two performance assessment tasks. The paper-and-pencil test comprises five multiple-choice (MC) items and two free-response items, which represents all test items on process skills released by the TIMSS (Appendices 4.12). The MC items assess students' abilities in "using tools, routine procedures, and science processes", and in "investigating the natural world", while the free-response items assess students' abilities in "investigating the natural world" only. The Chinese version used in Hong Kong TIMSS was adopted for the present study (Appendix 4.13)

From the five TIMSS performance tasks provided for Population Two which is equivalent to age 14, two were chosen, namely *Solutions* (Appendices 4.14 & 4.15) and *Elastic Band* (Appendices 4.16 & 4.17). They were chosen because they deal with a wider range of process skills than the other tasks, covering nearly all the process skills mentioned in the new syllabus.

A detailed matching between the process skills assessed by the TIMSS items used and the skills emphasized in the new curriculum is displayed in the Table 4.2.

TIMSS Test		Process skills specified in the new curriculum
Paper-&-pencil test items/ performance assessment tasks	**Performance expectations**	
Items 1,4	Investigating the natural world (controlling variables)	• Controlling variables
Items 2,5	Investigating the natural world (selecting appropriate apparatus)	• Selecting appropriate apparatus
Item 3	Using tools, routine procedures, and science processes (predicting data presented in graphical form)	• Predicting and interpreting data presented in graphical form
Items 6	Investigating the natural world (Suggesting methods to prove the existence of air)	• Devising methods for testing hypotheses
Item 7	Investigating the natural world (Suggesting materials to use and procedures to follow)	• Selecting appropriate apparatus and suggesting experimental procedures
Solutions	I. Planning investigation	• Proposing hypothesis and devising methods for testing them
	II. Conducting investigation and recording measurement in table	• Carrying out instructions for experiments • Handling equipment and apparatus properly and safely • Using tables to convey information
	III. Drawing conclusions about effect of temperature	• Analyzing data, drawing conclusions • Inferring from observations and experimental data • Interpreting data
	IV. Explaining conclusions	Not specified in the Syllabus
	V. Evaluating design and experiment; describing changes	Not specified in the Syllabus
Rubber Band	I. Measuring lengths as rings are added	• Observing carefully, measuring accurately
	II. Graphing results	• Using graphs to convey information
	III. Calculating increase in length of rubber band when rings are added	• Manipulating simple numerals and other data

	IV. Describing how rubber band length changes as more rings are added	• Describing results accurately • Interpreting scientific information • Communicating data presented in diagrammatic, numerical tabular and graphical forms
	V. Predicting increase in length of rubber band	• Predicting
	VI. Explaining reason for prediction	• Predicting
Not covered in TIMSS tests or tasks selected for this study		• Asking relevant questions
		• Classifying

(The process skills specified by the new curriculum were drawn from two sections of the Syllabus - "Objectives" and "Planning teaching and learning activities" since the skills contained in the two sections are not exactly identical.
Those skills in bracket are not specifically mentioned in TIMSS. They are inferred from the task itself.)

Table 4.2: Matching of skills covered by TIMSS items to skills emphasized by the new science curriculum

As indicated in Table 4.2, there is a close match between the measuring instrument and the skills emphasized in the new curriculum. *Solutions* is a more open investigation than *Elastic Band* and assesses more complex process skills. Only two process skills: "classifying" and "asking relevant questions" mentioned in the syllabus are not covered by TIMSS items. Conversely, two skills are assessed by TIMSS items, but not specifically mentioned in the Syllabus. These include "explaining conclusions" and "evaluating design and experiment, and describing changes". Yet, they are regarded as important skills to be assessed in particular the latter skill which is also closely related to problem solving, an ability emphasized in the new syllabus.

4.6.6 Procedures for administering the tests

The timetable for administration of the tests has already been indicated in Section 4.3.1. The three scales and the paper-and-pencil test were set out in one paper for ease of administration by the class teacher. A total of thirty minutes was allowed for the paper, but the time to administer the paper was chosen by the teacher. Students also completed the attitude and science self-concept scales at time of the pre-test. Only the pre-test sub-groups needed to answer the TIMSS items. The non pre-tested subgroups answered another set of test items drawn from TIMSS, but these were not scored. The purpose was to avoid the pre-tested sub-group being interfered by the other sub-group. In the post-test, both sub-groups completed the scales and the paper-and-pencil test. The question paper and the scales were distributed to the teacher in advance and collected back shortly after completion.

For the performance assessment, the teacher set aside a double period in the laboratory for students to conduct the tasks near the time when the paper test was administered. I took charge of the administration process with the help of the laboratory technician of the school. Only the pre-test sub-groups performed *Solutions* and *Elastic Band* in the pre-tests. Students in these sub-groups were each provided with a set of equipment and materials and be given half an hour to finish each assessment task as specified in the TIMSS Administration Manual. Because of the shortage of equipment and lack of space in the laboratory, half of the sub-group worked on *Solutions* first, while the other half worked on *Elastic Band.* After 30 minutes, the students exchanged equipment and started working on the other task for another half an hour. Any 'consumed' materials like hot water, tablets and graph paper were replenished with the help of the laboratory technician. The test items and the performance assessment tasks were scored using the TIMSS rubrics (TIMSS Performance Assessment Coding Committee, 1994).

4.6.7 Pilot test

The attitudes and science self-concepts scales, as well as TIMSS test items and performance assessment tasks were pilot tested before the first round of pre-tests in

1999. A class of Secondary 1 students from another secondary school completed both the paper test and the performance assessment tasks. 30 minutes were found to be sufficient for students to complete the paper-and-pencil test and the attitude scales. However, time was getting very tight for the performance assessment tasks. This was because a double laboratory period in Hong Kong secondary schools lasts only about 1 hour 10 minutes to 1 hour 20 minutes. Hence, very strict time control and speedy replenishment of materials were needed when administering the tasks in the main study.

The data collected from the pilot test for the three attitudinal scales were subjected to statistical analysis using SPSS to check for internal consistency. Answers to the negatively worded items - Items 4 and 11 were adjusted during data entry. For the attitudes to science scale, the Cronbach's alpha is found to be 0.69. However, with the removal of Item 9, the Cronbach's alpha is further increased to 0.83. This was probably because the meaning of the item was not clear enough to the students, resulting in differential interpretation. Hence, item 9 was abandoned in the main test.

Cronbach's alpha for attitude toward science curriculum scale and science self-concept scale in the pilot test were found to be 0.81 and 0.86 respectively, indicating that both scales had a high internal consistency.

4.6.8 Student interviews

Sampling

A small sample of students was selected from each class for interview. The sample was selected by splitting each class into two more or less equal halves according to their performance in the post-test. This created two groups, a "better" and a "poorer" groups. From each group, three students were drawn at random, making a sample of six students per class.

The interview procedure

The interviews were conducted shortly after the post-test. After the subjects were chosen, their teachers were informed so that they could arrange a suitable date and time with them, either during class or after school. The six students in each class were interviewed as a group. Group interviews were preferred because students should find this arrangement less intimidating, and hence should feel freer to explore and express their own views and feelings. At the start of the interview, the students were told of the purpose of the interview and the kinds of questions to be asked. They were then free to decide whether to participate or not. All students agreed to participate except for those that were absent on that date. Permission was sought from the students for audio taping the interview for further analysis.

The interview protocol

An interview protocol (Appendix 4.18) was designed to guide the interviews. Students were encouraged to talk freely about their experiences and feelings in a relaxed atmosphere. They were allowed to diverge at any point if they felt a need. At the start, TIMSS performance assessment tasks were used as a focal point for discussion. Participants were led to explore their feelings about doing these tasks. I asked questions like "What struck you most while performing such tasks?" and "How did the tasks compare to what you had done in class?" Then, I encouraged them to talk about the way they tackled the tasks and about any problems they encountered. I asked them to consider reasons why they found items difficult or easy. I then picked up leads from the performance tasks and invited students to talk more about their views on the curriculum, including the books and worksheets, and the ways practical work was conducted in the class. Finally, they were asked to suggest, from their perspectives as students, changes they would most like to see to the existing curriculum. Throughout the interview, I exercised caution not to encourage direct comments on personal qualities or competence of their teachers, but to focus on the lesson content and experiences they gained in class.

4.7 Summary of strategies

In this chapter, I have outlined the guiding framework and methodological design for the evaluation of the new Hong Kong junior secondary science curriculum The evaluation framework is based on a seven-level curriculum framework with the research questions and sub-questions incorporated into it to guide the design of the methodology.

The study employed a multi-method approach to collect evidence for describing the different levels of the curriculum, and to gauge the responses of various stakeholders, including planners, teachers and students on the curriculum process. This approach necessitated the merging of the positivistic and interpretive paradigms in designing appropriate methods. For the intended curriculum, qualitative methods were used including planner interviews and documentary analysis. These could lead to an in-depth understanding of the context of the reform and how planners' ideas were translated into intended practices. As the curriculum filters to the implemented level, the perceptions, beliefs, attitudes and behaviours of the teachers come into play. These were elicited by teacher interviews and a questionnaire survey. Lastly, quasi-experimentation was employed to obtain concrete evidence of students' learning outcomes from a comparative perspective. The quantitative data on student learning outcomes was validated by student interview data, which provides more personalized evidence. Finally, student outcomes were explained by relating them to the data of the intended and implemented curricula.

In the next three chapters, I will report the findings on the three curriculum levels in response to the first three research questions.

Chapter 5: Data analysis – the intended curriculum

5.1 Overview

This chapter deals with the analysis of the intended curriculum to provide answers to the first research question and its sub-questions –

The main question is:-

RQ1. "What is the context of the reform and what makes the new Hong Kong junior science curriculum distinctive from the previous curriculum?"

The sub-questions are:-

1.1 What are the driving forces behind the reform, and the principles that guide the development of the new curriculum?

1.2 How did curriculum planners translate their perceptions for reform into the official curriculum document?

1.3 What similarities and differences between the new and old curricula are apparent?

I report my findings with reference to the two sub-levels of the intended curriculum as appeared in the evaluation framework: the conceived and documented curricula, which correspond to the first two sub-questions. As both the conceived and documented curriculum will be considered in comparison with the old curriculum, Sub-question 3 will be discussed in conjunction with the other two.

5.2 The conceived curriculum

The conceived curriculum was mainly informed by the interviews conducted with the two curriculum planners: the curriculum officer responsible for coordinating the reform, and a tertiary member of the Science Subject Committee. The interview data were organized into three themes: 'context of the reform', 'distinctive features of the curriculum', and 'issues of concern'.

5.2.1 <u>Context of the reform</u>

The two planners concurred that the reform was driven by forces from both outside and within the system. Reform movements occurring elsewhere including the U.K, Australia and the US have generated new conceptual understanding and views about science education, while the information explosion posed new needs to students and society. The main concern was that the old curriculum, based on conventional approaches to teaching and learning science prevailing in the 70s, could no longer fulfill the contemporary roles of science education. The following extract from the curriculum officer interviewed put across this message forcefully.

> *In Hong Kong, the adoption of Science 70s represented an initial step to hands-on activities for development of personal knowledge. Teachers in those days were unfamiliar with the use of those kinds of activities in the classroom. And because the background of IS teachers were so varied, the 1986 syllabus spelt out clearly all the experiment to be conducted. This is necessary in order to avoid accidents occurring in the laboratories. This could be regarded as the historical role of the old syllabus. Now, this role has subsided as most IS teachers have gone through this learning process while they were in school. A side effect of the old curriculum is an exact correspondence between the document and textbook. There was no variation whatsoever. Emphasis was on completing worksheets rather than conducting activities according to the expected outcomes. It looked like attending a cookery class, which made learning in the classroom very superficial. No thinking was needed on the part of the students as to why they were required to do so and so...Students were even told what to observe, without thinking about the culture and history of science.*

She elaborated further on what the new curriculum should be like.

Science should be related to the creation of meaning for existing knowledge or to create new knowledge, but these were rare in HK. We think the same should happen here. To realize this aim, learning of science must include formulating hypotheses, making observation and drawing conclusions. In the old syllabus, no formulation of hypotheses was required, as thinking was not encouraged. Without hypotheses or predictions, no new knowledge will be created. A habit of thinking about things should be induced in students which they could use in future. We hope that students could think in the way as scientists did in the past.

The tertiary member also supported the adoption of an investigative approach but she did not see the "cookery book" approach as intrinsic to the old curriculum. Instead, she considered the problem as one created by the textbook, rather than by the original curriculum adopted from Scotland. She said the problem was that Hong Kong textbooks had become a manual which provided every procedure and answer for students.

At that time, the worksheets consisted of questions only, without a textbook. So, the teacher had to search for relevant materials to find out the answers. And they had to go through the experiments and investigate with students, as they were not provided with solutions. But with the building up of resources, textbooks became a manual, just like what I would do when I cook...say, adding a spoonful of sugars , two spoonfuls of salt, that kind of things. .... This defeated the whole purpose of doing experiments and resulted in a lack of emphasis on the development of students' process skills. The new curriculum was designed in the light of these shortcomings.

Thus, explicit in the planners' views is that the present reform should aim to change the old approach to a new one that encourages thinking and inquiry through a hypothetical-deductive approach. This approach was seen as an essential means for scientists to generate new knowledge. Hence by going through this process, students would appreciate how new knowledge is generated and their skills for inquiry developed as well.

Apart from a change in approach that better reflects the nature of science, both interviewees emphasized making science relevant to the everyday life as an important aspect of the reform. This is reflected in the following extracts:-.

> **Tertiary Member**: *The reform is intended for better integration, and although students do not continue to study science, they can still tackle science-related problems encountered in their daily lives. So we intended to make the curriculum more interesting and updated. That's why we added topics like Space Travel and to eliminate topics that were less interesting.*

> **Curriculum Officer**: *Owing to the information explosion, students are being bombarded by so-called health products, "weight losers" etc, which appear to have a scientific basis. Also of direct concern to students are controversial issues like possible health hazards posed by the electromagnetic waves emitted from cellular phones. We know that many students cease to study science after Year Three, therefore it is important for them to develop a "healthy scepticism" to these issues. Students should be aware that evidence is needed for drawing inferences or conclusions. These issues are not easy to teach but we will provide resources to teachers as far as possible e.g. news cuttings for class discussion. Our aim is to let students know they have to make decisions in future and these should be based on evidence rather than hearsay or claims made by other people.*

Apparently, this rationale for making science relevant to life is in line with the STS approach prevailing from the 1970s to the 2000s. The planners saw scientific evidence as the key to differentiating claims and hearsay from what was believable, and science learning should equip students with a "healthy skepticism" towards new claims. To achieve this, the curriculum was updated to include more contemporary STS themes.

Another apparent intention of the planners was to address the issue of inclusiveness and equity. More diversified learning experiences than in the previous curriculum were incorporated into the new curriculum to cater for the diversified abilities of students. The aim is to enable students to develop self-confidence and self-assurance in the process. The curriculum planner emphasized this point in the following comment.

> *This is part of our responsibility to provide students with a sense of satisfaction and help them recognize their ability. We encouraged teachers to give students a free hand to investigate and design experiments. ....some students are not suitable for paper-and-pencil tests. There are students who are good at making use of different things to make artefacts, e.g. making cars propelled by elastic bands. These activities should enhance self-confidence in students. We should let different sorts of students develop confidence through diversified means. This would not occur if the teacher provides all the knowledge.*

This comment has three implications. First, the new curriculum should be responsive to the needs of students of mixed abilities. Second, student-led investigations and construction of artifacts has the added utility of developing students' self-confidence and self-assurance. Third, these activities are regarded as more suitable for the less-academically inclined students who failed in the old curriculum that emphasized knowledge acquisition.

The Curriculum Officer did not concur with the view that the reform was driven by the poor performance of Hong Kong in TIMSS since it was initiated before the release of TIMSS results. In fact, she regarded the policy of changing from English to Chinese as the medium of instruction in most schools from Year One to Three had a more important role to play. The Curriculum Officer explained why the use of the mother tongue was considered important in learning science.

> *This could allow more opportunities for more "mature" discussion in class. With the use of the mother tongue, students would find it easier to express themselves, to ask questions and to record results. In the past many students cannot express themselves in English. Now, the whole learning atmosphere becomes very different.*

Thus the planners capitalized on the change in learning environment in the majority of Hong Kong secondary schools in the post-colonial era to introduce new approaches which have surely a greater demand on the use of language.

5.2.2 Distinctive features of the new curriculum

The planners emphasized three distinctive features of the curriculum: the adoption of scientific investigation as the central theme; the emphasis on the evolutionary nature of science and its limitations; and the contextualization of curricular contents to make them more relevant to students' everyday lives. In the following extract, the Curriculum Officer conveys the rationale of emphasizing investigation and her understanding of scientific investigation:-

> *Investigation was chosen as the central theme because the development of scientific knowledge is based on investigation. Science progresses as a result of investigations by scientists. So investigation is the essence of science education. Whether a practical activity can be considered as investigation really depends on how it is led by the teacher. E.g. the addition of sodium into water can make a good investigation because this could involve skills ranging from observation to making inferences. To me investigation is very broad, it can be fair tests, explorations, or surveys..... Why we consider investigation as a central theme is because this is how scientific knowledge and culture were originated.*

Investigations were considered in very broad terms. Students were regarded as engaging in investigative work as long as they applied a range of process skills as practiced by scientists. In essence, investigation was seen as an active inquiry into questions based on observations or other stimuli. Implicit in this view is that there is a certain scientific approach by which scientists develop knowledge and that students can learn this approach by mastering those process skills.

The Curriculum Cfficer also emphasized the evolutionary nature of science and its limitations as an important aspect in the new curriculum. This is to be conveyed through the inclusion of story telling about scientific discoveries as part of the content and teaching approaches. Besides, a contextual approach is used to introduce basic science concepts in line with the STS approach. The curriculum officer cited an example.

> *.. Space travel. Include basic concept to space journey as a bigger issue. We develop like this From Space Journey what basic concepts do students have to learn The end products is dynamics instead of static. We use big concepts like space journey otherwise those small concepts will disappear when they cease to learn science.*

To avoid the shortcomings of the old curriculum, which dictated everything from the teaching approach to the detailed procedure of practical activities, there was a deliberate attempt in the new curriculum to avoid detailed specifications of the contents and the practical activities. It was hoped that teachers would make their own professional judgment. This strategy was intended to increase the variety of textbooks and to give teachers a more flexible choice of activities suitable for their students. The Curriculum Officer underscored the instrumental role of teachers in implementing the curriculum.

We trust that teachers are the souls of education. Teachers are the only people to educate the minds of students. The implementation of all curriculum materials relies on the interpretation of teachers, including the asking of questions and the giving of answers, how to provoke thinking and how to put things into students' minds. The teacher is the key. Others like us can only provide assistance, like changing the curriculum or making our philosophy known to teachers. So the thinking of the teacher is of utmost importance. If the teacher doesn't change in thinking, teaching and learning will not change. Interaction is very important. The way the teacher asks or responses or follows up on students' answer will convey to students whether their answers are respected by the teacher, or whether the teacher would like to engage in thinking with the students, or in teaching students how to think. Only the teacher could realize this, ... We have conveyed our ideas through workshops for teachers."

The tertiary member echoed the importance of the teacher's role.

There is not a big difference in terms of the context of the activities [between the old and the new curriculum]. It really depends very much on how the teacher presents them. And that is the most important thing.

5.2.3 Issues of concern

Both interviewees were open in discussing the constraints or difficulties they were aware of. The Curriculum Planner commented on the difficulties of designing investigative tasks and the selection of topics to be covered:-

Investigations are more open-ended activities. Students need a knowledge structure..... not many topics are suitable for experimental investigation. Safety is an important consideration. Some small-scale investigations are suitable for carrying out in class, like making an object that floats and sinks in water, i.e. with the density equal to one. ...There are in fact not many suitable activities.

There are so many topics that are worth learning. We hoped to organize concepts in form of contextual approach or thematic approach. ....At one time, we had considered Sports science as an alternative topic. We had to look for topics at appropriate levels of difficulty. This was not easy because safety was our major concern. Also we had to face the difficulty of obtaining resources for developing new activities, which are less readily available as compared to activities in the old curriculum. For instance, in "Space Travel", it is difficult to explain to students how a spacecraft orbits around the Earth. There was a lot of compromising in selecting topics and coverage. We had to consider relevance of the topics, the degree of difficulty, and what we want our students to learn.

The tertiary member was particularly wary of the possible lack of teachers' support for the new curriculum.

In fact, I used the investigative approach in my institute a long time ago. But does that mean teachers would use such an approach in their actual teaching? In fact, we still observe teachers telling students the right answers in school. So there is a gap between what they learnt and what they actually practice. The source of the gap is worthy of further exploration, like time and resource constraints.... Teachers were bound by too many restrictions like having to meet very tight schedules. That would prevent them from implementing the kind of approach expected of them.... We need to allow them a certain period of time to master it. Moreover, resources, teacher education and support for school should be the areas that we should work on. The pressure of public examination and the streaming of students into Art and Science streams all have an impact on the curriculum.

The Curriculum Officer also shared this concern.

We wish them all to be good teachers. But we know teachers have to lot to do and many only teach IS as a supplementary subject or minor subject. Only a small percentage of teachers major in teaching IS and they are normally graduates from teacher colleges...What happens in schools is quite out of our control. Although we reached about 700 teachers through our seminars, as you know, some teachers cannot be "changed". So we could only encourage and provide opportunities. We would talk to them frequently and arrange sharing *among teachers.*

According to the Curriculum Planner, training had been provided to teachers before and after the beginning of the first year of implementation. Training has been provided in form of teacher seminars and workshops, web-based training courses for enrichment of teachers' concepts on physics in everyday life, like electromagnetic radiation and space travel. A booklet and some power-point presentations were produced to introduce science investigations, with examples of investigative activities to illustrate each step. She considered these forms of support suitable for teachers as she perceived that teachers would not like to be taught through formal courses.

Because of the shortage of manpower responsible for curriculum development, the Curriculum Officer conceded that there wasn't any systematic trial of the whole curriculum. Yet they had received feedback from the trials of individual investigative activities in some schools as part of their ongoing projects. She talked about the outcomes of these activities.

> *I had met teachers who were reluctant to participate in trying out the new approach. Some teachers did not know how to assess investigation skills at the start. E.g. some gave high marks to projects which didn't even mention controlling variables. (After gaining more experiences), in subsequent sharing sessions, those teachers were able to tell us the process that they went through from not knowing what to do to gaining confidence after experiencing success. We did receive a lot of feedback. This told us that we have to go through a process before change will take place. There were also teachers who told me that they didn't know how to teach according to the new textbooks. So I could consider all those teachers participating in the test as very enthusiastic, but I dare not generalize this to other teachers.*

Yet, the Curriculum Planner was quite confident that changes would take place in the long term, as indicated by the following comments:

> *I will take this [new curriculum] as an instrument for initiating changes in teaching and learning. With the new syllabus, teachers will come to learn how to change. A group of schools is already changing under the initiation of some enthusiastic teachers, so the effect is multiplying and a network of teachers has already been formed. The scene is encouraging though there are still many teachers "hiding" somewhere. But since the whole atmosphere is poised for changes, these teachers should change some days in the future.*

By contrast, the Tertiary Member sounds less affirmative in this respect.

> *I would like to see that the attitudes of teachers really change and textbook publishers produce better books. Students couldn't tell the differences. The difference is in how the teacher perceives the new curriculum and the kind of support provided by the textbook publishers since the way that Hong Kong teachers teach is very much governed by the textbook in terms of contents and teaching materials....If the school curriculum is till that tight, and the workload of teachers as heavy as it is now, it is difficult to require them to work in this way..... This (the class size) is a source of difficulty. With four to six students in a group, many teachers reflected that students might not even have an opportunity to perform experiments by themselves.*

5.2.4 Discussion

The above interview portrayal provides a more in-depth understanding of the context and driving forces for the present reform. The reform was initiated as a result of the perceived inadequacy of the old curriculum to meet current needs and to reflect the nature of science as a discipline. From the account of the planners, the following assumptions were identified regarding the rationale, aims, teaching approaches, and possible opportunities and constraints which constitute the planners' conceived curriculum:

1. The initiation of the new curriculum was in response to the new conceptions brought about by reform movements in western countries.

2. The guided discovery approach had fulfilled its historical role of making science learning more meaningful for Hong Kong students. Learning in science needs to be more in-depth in terms of development of skills characteristics of those employed by scientists.

3. Scientists employ a certain scientific method for generating knowledge which students can gradually master through developing their process skills.

4. Investigation was considered as the essence of science education. Employing an investigative approach helps students develop a habit of scientific thinking and a wide range of skills such as observing, making hypotheses that are thought to be essential for the development of new knowledge.

5. Emphasizing diversified learning modes including investigation, discussion and construction of artefacts would cater for students with different abilities and boost their self-confidence and self-assurance.

6. Studying science topics relevant to the daily life would induce a " healthy skepticism" in students, which enabled them to make informed decisions in future.

7. The new policy of using the mother tongue as the medium of teaching provided a favourable environment for the introduction of a more investigation-based approach. This is because learning through investigation would place a greater demand on students' language skills. Using the mother tongue could reduce the language barrier.

8. The avoidance of detailed specifications of students' activities in the curriculum guide would give teachers a freer hand to plan for activities that best cater for students' needs.

9. Suitable investigative activities were limited. These types of activities had a safety implication and therefore should be properly chosen.

10. Whether the investigative approach could be implemented as intended would depend very much on the interpretation and actual practices of the teacher.

11. Full implementation of the new approach in teaching I.S. was likely to be a long-term goal in the light of the different degrees of teachers' readiness to adopt the new approach.

12. The overloaded curriculum, teachers' heavy workload and large class size may limit the degree of implementation.

13. Training in form of seminars and workshops and support in form of booklets, CD-ROMs and sharing of good practices were considered appropriate means for induction of teachers to the new curriculum as teachers would prefer these to more formal training programmes.

These beliefs or assumptions of the planners should have guided the design of the written curriculum. How these were distilled to various components of the documented curriculum are analysed in the next section.

5.3 The documented curriculum

5.3.1 Rationale

An extract of the new science syllabus containing the rationale, aims and objectives is provided in Appendix 5.1. As stated in the *Introduction* of the syllabus:-

> *"Science education has to prepare students to cope with the rapid advancement in science and technology. The primary aim of science education at the junior secondary level is to ensure that students develop the necessary scientific and technological knowledge and skills to live and work in the 21st century." (HKCDC, 1998, p.2)*

This statement embraces the rationale perceived by the curriculum planners, i.e. to help students cope with the advancement in the scientific and technological field. This is in marked contrast with the old syllabus which says nothing specific about learning of science.

5.3.2 Aims and objectives

To explore how the intentions of the curriculum planners were reflected in the aims and objectives of the new curriculum, and to facilitate comparison with the old curriculum, I re-categorized the aims and objectives of both curricula into six common themes as shown in Fig. 5.1. These are *knowledge, cognitive skills, language of science, scientific attitudes, attitudes towards science and society,* and *nature of science.*

Strand	New curriculum		Old curriculum	
	Aim	Objective	Aim	Objective
Knowledge	Acquire the basic scientific knowledge and concepts for living in and contributing to a scientific and technological world	**Knowledge and understanding:** Some phenomena, facts and concepts in science; Some scientific vocabulary and terminology; Some applications of science in society and students' everyday life	**Some knowledge of the empirical world around them** – Reduce the emphasis on the factual content of the syllabus, to fight shy of any content which seems to have more value to the specialist scientist and to include only those items suited to the stage of development of the children.	**Knowledge and understanding:** Knowledge of some facts and concepts concerning the environment Knowledge of the use of appropriate instruments in scientific experiments An adequate scientific vocabulary Comprehension of some basic concepts in science so that they can be used in familiar situations
Process skills	Develop the ability to enquire and to solve problems	**Scientific method and problems solving skills:** Ask relevant questions, suggest ideas and make predictions; Select and apply facts and concepts learnt to solve problems; Propose hypotheses and devise methods for testing them; Analyse data, draw conclusions and make further predictions; **Laboratory techniques:** Handle apparatus and chemicals safely and properly; Carry out instructions for experiments; Observe and describe objects and experimental results accurately; Select appropriate apparatus and suggest experimental procedures **Decision making skills:** Make objective judgements based on data and arguments presented with scientific, ethical, economic, political and social considerations; Support value judgement using appropriate and relevant scientific facts and knowledge	**An ability to observe critically** – Teachers will present the situation for learning such that correct answers will not be available to the pupils in advance. An ability to solve problems and think scientifically – Through investigative methods the pupils are required to react continuously in a thinking situation.	**Knowledge and understanding:** Ability to select relevant knowledge and apply it to new situations Ability to analyse data and draw conclusions Ability to think and act creatively in science **Practical skills:** Some simple scientific skills Some experimental techniques involving several skills

Theme	New curriculum		Old curriculum	
	Aims	Objective	Aim	Objective
Language of science	Be acquainted with the language of science and be equipped with the skills in communicating ideas in science related contexts	***Communication skills:*** Extract relevant information from a variety of sources; Manipulate simple numerical and other data; Interpret scientific information from data presented in diagrammatic, numerical, tabular and graphical forms; Organise and present information in a clear and orderly manner; Argue for or against the use of science in technological situations based on scientific, ethical , economic, political and social considerations; Communicate scientific ideas and values with one another	An introduction to the vocabulary and grammar of science – The reading, listening and viewing of everyone is becoming more and more filled with scientific language used to describe the ever-increasing influences of science on our daily lives. This language, in words or otherwise, helps to improve pupils' communication skills	***Knowledge and understanding:*** Ability to communicate using this vocabulary
Scientific attitudes	Develop curiosity and interest in science	***Attitude:*** Develop curiosity and interest in science; Develop personal integrity through honest recording of experimental data	NIL	***Attitudes:*** Interest and enjoyment in science An objectivity in observation and in assessing observations

Theme	New curriculum		Old curriculum	
	Aim	Objective	Aim	Objective
Attitudes towards areas in relation to science or society	Recognise the usefulness and limitations of science, technology and society and develop an attitude of responsible citizenship, including respect for the environment and commitment to the wise use of resources	Be aware of the importance of the safety of oneself and others in the laboratory and be committed to safe practices in daily life; Develop an awareness of scientific advancement and its social, economic, environmental and technological implications; Be willing to communicate and comment on issues related to science and respect the decisions of others; Develop a positive attitude in enhancing personal and community health; Show concern for the care of the environment and a willingness to contribute to it	An understanding of the relevance of science to the world beyond school and to the needs of a changing society. **An awareness of the culture which is science –** The corpus of knowledge in science is growing at an explosive rate, and the effect of this growth is to alter not only our physical conditions but also our morals, our ethics, our interests and our whole cultural development. *(*This aim is related both to "attitude" and "nature of science")*	Awareness of the inter-relationship of the different disciplines of science Awareness of the relationship of science to other aspects of the curriculum Awareness of the contribution of science to the economic and social life of the community
Nature of science	Be able to appreciate and understand the evolutionary nature of scientific knowledge	NIL		Nil

Table 5.1: Matching of aims and objectives of the new and old science curriculum

The aims and objectives of the new curriculum are in line with the intentions of the curriculum planners except that no objectives were found to correspond to the nature of science, which was emphasized by the curriculum planners. When the aims of the two curricula were compared, a number of similarities were observed. Both curricula stress on (1) knowledge and skills, in particular the ability to enquire and solve problems using a scientific method; (2) the language of science and skills to communicate scientific ideas and issue; and (3) scientific attitudes, though these are stated only in the objectives instead of in the aims in the old syllabus. Despite these similarities, the new curriculum are distinctive from the old curriculum in three major aspects:-

Increased emphasis on process skills

Although both curricula emphasize the investigative method. The old curriculum emphasizes critical observation, reflecting an emphasis on the inductive approach as a means to develop scientific knowledge. In the new curriculum, the ability for inquiry are stressed.. A comparison of the objectives of the two curricula shows that in the new curriculum, the skills employed are characteristic of a hypothetical-deductive approach. These skills are most notably asking questions, making predictions, proposing hypotheses, and devising methods for testing them. A full list of skills is included in another section of the syllabus provided in Appendix 5.2. An obvious omission from this list is the skill of evaluating design of investigations, which is supposed to be important in judging the credibility of evidence. In the old syllabus, the objectives related to skills were vaguely mentioned. Students were expected to think scientifically but only the skills of analyzing data and drawing conclusion was specifically spelt out. This further implies that the inductive approach was dominant in the old curriculum.

As for communication skills, the old syllabus only mentioned the use of the language of science to aid in communication in a social context. The new syllabus elaborates this to a greater extent to include manipulating data and interpreting information from data. It further specifies that students should make use of the language of science to argue and discuss with others about scientific issues, leading to value judgment.

Increased emphasis on attitudes and decision-making skills

Although both curricula stress the development of attitudes toward science and its relation to society, the new curriculum takes a step further to inculcate in students positive attitudes and a willingness and commitment to contribute to solving science-related societal and environmental problems. This evidence is further reinforced by an emphasis on decision-making skills for making informed judgments based on data and arguments. This category of skills was untouched by the old curriculum.

Emphasis on the nature of science

The new curriculum emphasizes the nature of science, which is seen to be constantly evolving. By contrast, the old curriculum recognized the rapid growth of scientific knowledge and its subsequent effects on human culture, the interconnecting nature of different science disciplines, and their relationships to other subjects. However, this emphasis seems to diminish in importance when the "aims" are translated into the "objectives".

5.3.3 Topics and content

As displayed in Table 5.2, there is a shift in content emphasis in the new curriculum. Some conceptual contents like plant reproduction, classification of plants, order of reactivity of metals, work done and enzymes now give way to areas more relevant to students daily experiences, or global issues including protection of endangered species, birth control, *in vitro* fertilization, smoking, Air Pollution Index, noise pollution and composite materials. Two units, *Making Heat Flow* and *Electricity and Electronics*, were discarded and replaced by *Materials of the Modern World* and *Light, Colours and Beyond.* The contents of these two units, which include plastic, composite materials and electromagnetic radiation, have greater relevance to contemporary life.

Unit of old curriculum	Unit of new curriculum	Addition of topic areas	Deletion of topic areas
1.Introducing science	1. Introducing science	Few or none	Few or none
2.Looking at living things	2.Looking at living things	Protection of endangered species; Effects of man's activities on wild life	Classification of plants
3.Energy	4.Energy	Few or none	Few or none
4. Matter as particles	**6.Matter as particles	Few or none	Few or none
5, Solvents and solution	5.The wonderful solvent-water	Need to treat waste water before discharging; Sewage treatment charges	Explanation of change of state using particle model; Effect of salt on melting point and boiling point; Simple paper chromatography; Colloidal solutions and emulsions
6. Cells and Reproduction	3.Cells and human reproduction	Pregnancy; Family planning; Birth control; *In vitro* fertilization; Sexually transmitted diseases	Reproduction in plants
7. Living things and air	7. Living things and air	The fire triangle; Effect of smoking and polluted air on our breathing system; Air pollution index	Comparison of respiration and combustion
8. Making use of electricity	8. Making use of electricity	Voltage; Power of electrical appliances; Cost of electricity	Chemical and motor effects of currents
9. Making heat flow	cancelled	n.a.	n.a.

10. Hydrogen, common acids and alkalis	10. Common acids and alkalis	Few or none	Electrolysis of water; Hydrogen; Reactivity of metals; Concentration; Quantitative aspects of neutralization
11. Detecting the environment	11. Sensing the environment	Sound level (dB); Noise pollution control; Main parts of brain and their functions ; Effects of drugs and solvents on our senses; Breathalyser	The camera and the eye
12. Forces and movement	9. Space travel	Space journey; Gravity-free motion; Weightlessness; Space suits for sustaining life; Space exploration and the impact of space programmes on man	Law of lever; Lever systems; Work done and energy changes
13. Food and transport	12. Healthy body	Health problems with processed food; Food additives; Effects of fatty food on our circulatory system; Exercises and health	Food chain and food web; Dentition and diet; Enzymes; Water balance; Kidney and its functions; Nutrients for plant growth; Absorption and transport of water in plants
14. Materials from the Earth	13.Metals	Alloys; Environmental problems associated with the disposal of used metals	Origin and structure of Earth; Soil; Destructive distillation; Materials from the sea
	14. Materials of the modern world	Making plastics from crude oil; Common examples of plastics; Advantages of using plastics; Environmental problems with the disposal of plastics; Recycling; Composite materials	
15.Electricity and electronics	cancelled	n.a	n.a.
	15. Light, colours and beyond	Law of reflection; dispersion; colour spectrum; invisible radiation; EM spectrum; Use of radio waves to carry information; refraction, images through lenses; total internal reflection	n.a.

** The sequence of some old topics has also changed. (The figure was adapted from an information sheet compiled by the CDI.)

Table 5.2: Comparison of topics and contents between the new and old curricula

5.3.4 Suggested teaching and learning activities

The new syllabus suggests a total of 277 teaching and learning activities for S1-3. These were matched to the main objectives of the syllabus to reflect the consistency with the objectives. Table 5.3 records the coverage of the objectives.

Code	Objectives	Percentage of activities	
		Old Curriculum	New Curriculum
	Knowledge and understanding:		
K1*	Some phenomena, facts and concepts in science	-	-
K2*	Some scientific vocabulary and terminology	-	-
K3	Some applications of science in society and students' everyday life	20%	34%
	Scientific methods and problems solving skill:		
S1	Ask relevant questions, suggest ideas and make predictions	1%	7%
S2	Select and apply facts and concepts learnt to solve problems	14%	16%
S3	Propose hypotheses and devise methods for testing them	2%	11%
S4	Analysis data, draw conclusions and make further predictions	40%	22%
	Laboratory techniques:		
L1	Handle apparatus and chemicals safely and properly	23%	21%
L2	Carry out instructions for experiments	52%	28%
L3	Observe and describe objects and experimental results accurately	68%	61%
L4	Select appropriate apparatus and suggest experimental procedures	0%	8%
	Decision making skills:		
D	Make objective judgements based on data and arguments presented with scientific, ethical, economic, political and social considerations. Support value judgement using appropriate and relevant scientific facts and knowledge.	2%	6%
	Communication skills:		
C1	Extract relevant information from a variety of sources	4%	22%
C2#	Manipulate simple numerical and other data; Interpret scientific information from data presented in diagrammatic, numerical, tabular and graphical forms; Organise and present information in a clear and orderly manner.	15%	24%
C3	Argue for or against the use of science in technological situations based on scientific, ethical, economic, political and social considerations	0%	2%
C4	Communicate scientific ideas and values with one another	21%	10%
	Attitude:		

A1*	Develop curiosity and interest in science		
A2	Be aware of the importance of the safety of oneself and others in the laboratory and be committed to safe practices in daily life	3%	4%
A3	Develop personal integrity through honest recording of experimental data		
A4	Develop an awareness of scientific advancement and its social, economic, environmental and technological implications	6%	11%
A5	Be willing to communicate and comment on issues related to science and respect the decisions of others	0%	3%
A6	Develop a positive attitude in enhancing personal and community health	2%	11%
A7	Show concern for the care of the environment and a willingness to contribute to it.	3%	6%

Total activities in old curriculum = 347
Total activities in new curriculum = 277
* These objectives were not included in the matching because they were found to be covered by most of the activities
# This consists of three closely related objectives grouped together

Table 5.3: Matching of suggested teaching and learning activities for the old and new curricula to the objectives of the new curriculum

The results of the coding was validated by randomly choosing about 10% of the activities from both the new and the old curricula for independent coding by two coders. The two coders are my colleagues specializing in science education. The extent of agreement between my own coding and that of the second and third coder were 78% and 70% respectively. Although these percentages are not high, they were regarded as acceptable given the wide range of objectives, and the absence of detailed specifications for the activities in the new syllabus.

The findings showed a number of distinctive features in the activities suggeseted by the new syllabus when compared with the old one. They are listed as follows:

1. There are more activities on the applications of science in society and students' everyday life.

2. There is a greater coverage of scientific methods and problem solving skills except for *analyzing data, drawing conclusion and making further prediction.*
3. There are fewer opportunities for developing laboratory techniques except for *selecting appropriate apparatus and suggesting experimental procedures.*
4. A greater emphasis is placed on decision-making skills and communication skills, in particular, extracting relevant information from a variety of sources.
5. Emphasis is increased on all ranges of attitudinal objectives.
6. Fewer number of activities are suggested.

These features are in general consistent with the objectives of the curriculum, that is, making science learning more relevant to the daily life and emphasizing inquiry as a tool for developing skills and knowledge. It could still be argued that some skills like observing and carrying out instructions are emphasized more than the others such as asking questions, proposing hypotheses and devising experimental methods. The fewer number of activities seems to be consistent with the planners' intention to make the syllabus more flexible and less dictating. The analysis of suggested teaching approaches in the following paragraph shed more light on the nature of these teaching activities.

As shown by the planner interviews, one of their intentions was to provide more diversified learning experiences to students. In order to identify to what degree this was translated into the curriculum, the suggested teaching activities were analyzed and categorized to reflect the range and frequency of teaching strategies or methods employed. Table 5.4 displayed the results.

Teaching strategy or approach	Percentage of activities	
	Old Curriculum	New Curriculum
Teacher-led practical work (expts)	57	39
Demonstration	5	11
Discussion	27	9
Library search -- obtain information	2	10
Investigation	0	7
Watching Video	0	5
Making/design models	2	5
Data analysis	3	5
Studying models	5	3
Collecting newspaper clippings	0	2
Telling stories	< 1	1
Surveys	1	1
Visits	0	1
Debates	0	1
Project work/Case study	3	1
Quiz	0	1
Reading articles	< 1	< 1
Games	0	< 1
Talks	0	< 1
Design slogans	0	< 1

Table 5.4 Matching of suggested activities to teaching strategies for the new curriculum

Table 5.4 shows that a wider range of teaching strategies are suggested for the new curriculum compared with the old curriculum. There is less teacher-led practical work, but more activities, like debates, visits and designing slogans. Apparently, these less traditional types of activities are intended to make science more relevant to society and to develop students' decision-making skills and other attitudes as detailed in the objectives of the syllabus. The use of discussion was much more frequent in the old curriculum, but on closer examination, discussion was mainly used to elicit scientific concepts like particle theories or to introduce applications of concepts. In the new curriculum, discussions are intended to bring out science-related social issues. There was a greater use of project work in the old curriculum, but this was heavily biased towards constructing electronic devices in the Unit of Electricity and Electronics for Year Three.

Although there is less teacher-directed and guided discovery type of experimental work in the new curriculum, this type of work remains the most dominant type of activities. As mentioned previously, the planners ascribed a process skill to each of the activities, assuming the activity will lead to the development of that particular skill. Despite this, judging from the nature of most of these activities, their prime focus is on the development of knowledge and concepts, which is similar to the emphasis of the old syllabus. To illustrate this point, I extract some suggested activities for Secondary 1 from the new syllabus as follows:

Topic	Content	Suggested activity
3.1 The basic unit of living things (Unit 3: Cells and human reproduction)	Cells as basic units of living things which can divide and grow Basic structure of a cell: nucleus, cytoplasm, cell membrane, cell wall (in plants)	1. Through a video imaging device and microscope, examine the various types of cells in man (OB*) 2. Prepared slides of plant and animal cells (e.g. onion and ox eye cells) and observe under the microscope (OB, EA)
6.1 States of matter (Unit 6: Matter as particles)	States of matter: solid, liquid & gas Properties of solids, liquids & gases: ● Solids – have fixed volume & shape; ● Liquids – have fixed volume & shape; ● Gases – have no fixed shape & no fixed volume Change of state of matter takes place at a fixed temperature: melting, freezing and boiling	1. Classify matter into solids, liquids and gases (CS) 2. Experiment to compare the change of volume of some solids, liquids and gases when compressed (PD) 3. Experiment to find the melting and boiling point of water (EA) 4. Find the melting point of a solid, e.g. stearic acid (MS, EA) 5. Discuss how change of state can be put to use in everyday life

*The key to the abbreviations of skills is provided in Appendix 4.4.

Table 5.5: Examples of teaching activities matched to the content of the new syllabus

Table 5.4 also shows that investigation accounts for 7% of the activities in the new curriculum comparing to none in the old one. This reflects some shift in emphasis from the close-ended type of practical work to open-ended inquiry, which is in line with the rationale of the reform. According to the syllabus, these activities bear the following characteristics:

> *These activities should involve a fairly genuine form of 'experimenting', including proposing questions or hypotheses for investigating, and devising ways to find answers. It also involves deciding on the type of equipment required, and measurements to be made, as well as identifying the variables involved and manipulating the variables so that the effect of only variable can be observed in any one experiment. (HKCDC 1998, p.26)*
>
> *There is a growing belief that students construct their own knowledge and that students learn more effectively through investigations. Investigative work not only gives students opportunities to bring together and express their understanding of scientific concepts and skills – often in a practical context – but it also provides concrete situations in which students' existing understanding of scientific knowledge can be challenged and hence, new learning can occur. (HKCDC 1998 p.26)*

Hence, these activities are supposed to be genuine investigations mimicking the work of scientists. They are to be conducted in a hypothetical-deductive manner. The planners also argue that "efforts should be initially directed at teaching explicitly each of the skills through the use of appropriate activities, and then finally helping students integrate some or all of these skills in experimenting and carrying out investigations" (HKCDC 1998, p16). Thus teaching students to investigate is assumed to be a systematic process which should begin by developing their mastery of individual process skills before they are able to conduct complete investigations. Moreover, science investigation is viewed as an important means for students to construct or reconstruct their own knowledge based on the outcomes of the inquiry. Table 5.6

displays all the investigations suggested for students from S1-3.

Year	Unit	Activity
One	Introducing science	Design and carry out a fair test** (The core version of this activity is to carry out a simple scientific investigation)
	Energy	Perform a fair test to compare the energy stored in different stretched elastic bands
	The wonderful solvent – water	Design experiments to purify muddy water and perform purification experiments of students' own design
		Investigate the factors affecting the rate of evaporation**
		Investigate the factors affecting the rate of dissolving**
		Perform a fair test to find the best solvent for an oil stain on a cloth**
Two	Living things and air	Fair tests to find out which brand of snacks contains the greatest amount of energy
		Investigate the necessary conditions for photosynthesis: carbon dioxide, light and chlorophyll**
	Making use of electricity	Design a circuit to test for insulators and conductors
		Carry out fair tests to investigate factors affecting the resistance of a wire**
	Space travel	Make the fastest 'balloon rocket'
		Investigate the factors which affect the fall of a parachute**
	Common acids and alkalis	Design an experiment to find out the strength of vinegar needed to preserve fruits at room temperature for at least a month
		Design an experiment to find out the effect of different pH on the prevention of apple browning**
Three	A healthy body	Design experiments to investigate the preservative effect of sorbic acid (or other preservative) on fresh bread from the bakery
	Materials of the modern world	Test the strength of different plastics**
		Compare the strength of concrete and reinforced concrete / plywood and wood
	Light, colours and beyond	Design a device to help a dentist see the back of your teeth / a child to see over a tall fence
		Design a lighting system for a restaurant with due consideration for the preferences of the target customers**

** These are extension activities suggested for the more able students.

Table 5.6: A full list of investigations designed for Secondary 1-3 in the new syllabus

Most of these activities are new except for a few which are open-ended versions of similar activities in the old syllabus. In most of these activities, there seems to be an intention to decouple processes from the acquisition of basic or classical scientific concepts, representing a major departure from the old approach. However, of the nineteen investigative activities suggested, ten were treated as extension activities for more able students, leaving only nine core activities for the whole three-year course. The adequacy of this quantity is debatable, but as explained by the curriculum officer, safety concerns and the relevance of the activity to the contents had imposed a constraint on the design of these activities.

Compared with the old curriculum, students are more frequently engaged in learning through different channels or media, including library search, watching videos, reading articles, collecting newspaper clippings, analyzing data and visiting places of scientific interest. From the skills ascribed by the planners, these strategies were intended to develop students' communicative skills and to relate science to their everyday lives.

5.3.5 Assessment

Assessment appears to receive less attention than other aspects in the new syllabus. Brief and general recommendations of assessment methods are included. The guidelines on assessment extracted from the new syllabus are provided at Appendix 5.2. These assessment methods were described under three categories: assessment of knowledge, understanding and application of science concepts, assessment of science skills, and assessment of attitudes. (HKCDC 1998)

For assessment of knowledge, understanding and application of science concepts, oral questioning, class assignments and paper-and-pencil tests are recommended. It is suggested that class assignment requires students to think and work actively, emphasizing the application of science concepts. The possibilities suggested include library search, collecting of information, visits, writing essays, designing a new device, assembling a toy model, and collecting newspaper cuttings. The syllabus also stresses that "when applied appropriately and imaginatively, paper-and-pencil tests and written assignments can be used to test the higher order thinking skills in addition to recall and understanding of facts." (HKCDC 1998, p.128)

To assess science skills, the syllabus suggests that more suitable methods are practical assessment and project work. Investigative projects which can assess enquiry skills such as "identifying problems, formulating hypothesis and designing strategies to solve problems" are recommended. (HKCDC 1998, p.128) Attitude assessments are recommended to take place over a period of time to show the progress that students make. Observing behaviour, asking students to write essays and using questionnaires are suggested. In spite of all these recommendations, no concrete suggestions or exemplary assessment tasks were included in the syllabus.

5.3.6 Discussion

As reflected by the curriculum analysis, the documented curriculum seems to be consistent with the conceived curriculum. Three trends are shown in both sets of data.

***Trend One*:**

The new curriculum seeks to reflect to a fuller extent the nature of science in classroom teaching. It introduces the hypothetical-deductive approach as a more rigorous way of obtaining scientific knowledge, which the planners thought to be able to reflect the scientists' way of knowing. Open investigations were put into place to institutionalize this hypothetical-deductive approach. To train students on the use of the scientific approach, leading ultimately to open investigations, a systematic development of process skills are stressed such as asking questions, formulating hypotheses and predicting. A stronger emphasis is also placed on communication skills in interpreting information and presenting arguments.

Trend Two:

Science contents are made more relevant to society and to the everyday lives of students. This was achieved by the addition of new topics that reflect contemporary issues, and by employing more diversified teaching strategies to increase students' awareness of those issues. Coupled with these is an increased emphasis on developing attitudes, decision-making abilities and communication skills, leading to a scientific literate and responsible citizenship.

Trend Three:

The evolution of scientific knowledge are emphasized in the aims of the new curriculum, and stressed by the planners during the interview. However, this emphasis becomes less obvious when moving from aims to detailed specifications of contents and activities in the syllabus. Apart from presenting scientific knowledge as a product of investigation, these concepts are inculcated in students mainly through telling stories of scientific discoveries in Unit 1. A few examples are provided to illustrate the evolution of scientific knowledge in Unit 13 (Discovery and use of metals in relation to their ease of extraction and availability – copper age, bronze age, and the iron age), and Unit 15 (Discovery of the production, transmission and detection of radio waves).

Inconsistency between the conceived and documented curriculum

Despite these consistent trends, there were compromises in translating the planners' intent and the aims of the syllabus into the suggested teaching content. Teacher-led practical work, serving the dual purpose of developing concepts and processes, continues to dominate. Judging from the modest number of open-ended investigations, opportunities remain rather limited for the development of integrated process skills. "Evaluation of investigations", an important integrated skill, is omitted from the list of process skills. Furthermore, there is a tendency to consider open-ended investigations as extension activities for more able students, leaving only a handful to the average students for each year. This seems contradictory to the planners' intentions to engage students from a wide range of abilities in investigations for enhancing their self-confidence and self-assurance. Besides, the syllabus does not spell out clearly how to assess process skills or how to ensure that this happens in the classroom context. This casts doubts as to whether the syllabus can bring about real changes in this outcome, which is so central to the present reform.

5.4 Summary

In this chapter, I scrutinize, from the perspective of a critical outsider, the context of the reform as viewed by the planners, which constitutes the conceived curriculum, and the different components of the documented curriculum. In response to Sub-question 1.1, the reform mirrors to a considerable extent reform movements occurring elsewhere in that it was driven by a combination of forces. In contrast with the previous curriculum, political influences were not obvious in the present reform. Yet, it can be argued that the political transition in Hong Kong had exerted a subtle influence through the mother-tongue teaching policy, a political decision in the post-colonial era. This was seen by the curriculum planners as a golden opportunity for designing a curriculum which emphasizes more student-centred work and a greater use of language in communication.

The major pressure for the present reform originated from the personal-social and educational context. From a personal-social perspective, the reform was a response to the increasing demand to make the new science curriculum more relevant to everyday lives in the light of the increased permeation of science and technology in society. The change was expected to equip students with the necessary knowledge base and decision-making skills for making informed decisions as regard science-related social issues affecting human lives. From the perspective of science education, the reform was a result of the growing dissatisfaction with the old curriculum in reflecting the nature of science. The old guided discovery approach was far from what is regarded as typical of the work of scientists. The planners asserted that the rediscovery of authoritative knowledge through a set of "cookbook recipes" did not lead to generation of science knowledge. The reform sought to institutionalize the view that science is a tentative body of knowledge that constantly evolves as driven by a hypothetical-deductive type of investigation.

One notable background feature about the present reform is that unlike many of Hong Kong's neighbouring countries, the reform was not driven by outcomes of international comparison of student achievements, nor was there evidence for the influence of economic forces.

The findings of this chapter also provide an answer to Sub-questions 1.2 and 1.3. The curriculum planners have obviously introduced a more genuine form of investigative approach as a central part of the new curriculum framework. Students are expected to learn this approach by engaging themselves in practical activities for developing various process skills, and then in open investigations for integrating those skills. Through this process, students are led to appreciate the nature of science. The contents are made more relevant to the everyday life, with a stronger emphasis on science-technology-society. More diversified teaching approaches are employed to reflect these new emphases and to cater for the needs of students with a wide range of abilities.

Despite these, there is inconsistency between the planners' intentions and the documented curriculum as evidenced by the limited opportunities for the average students to perform investigations and the under-emphasis of assessment measures for assessing new outcomes.

Amidst these changes, teachers were considered crucial to the success of the reform. This is particularly the case as the syllabus provides only broad guidelines instead of detailed specifications as in the old syllabus. Teachers were encouraged to adapt the documented curriculum to suit the needs of their students. This makes the teacher an increasingly important variable in the present reform. The curriculum planners hoped that there would be a greater variety of textbooks to provide teachers with a wider choice of activities. Also, to support teachers in implementing the new curriculum, teacher training was provided in form of seminars for sharing good practices amongst teachers, and through provision of resource materials such as booklets introducing scientific investigations and CD-ROMs to support teaching of specific topics. Yet a more formal type of in-service training course was regarded unnecessary and not to be welcome by teachers.

The curriculum planners were pragmatic in regarding the reform as a long-term process, and teachers as the key to success. How teachers respond to the new curriculum will be dealt with in the next chapter.

Chapter 6: Data analysis – the implemented curriculum

6.1 Overview

This chapter addresses the second research question.

The main question is:

RQ2. Did teachers implement the new curriculum as intended by curriculum planners, particularly with respect to the investigative approach?

The sub-questions are:

2.1 How do teachers perceive the new curriculum? To what extent are teachers' perceptions in line with the intended curriculum?

2.2 How does the implemented curriculum differ from the intended curriculum teachers perceive?

2.2 What opportunities and constraints are present? How do they affect implementation?

Data collected from the teacher questionnaire and interviews were analysed. The quantitative data in this chapter and the next was analysed using the Statistical Package for Social Sciences (SPSS). A brief description of the statistics used in these two chapters is provided in Appendix 6.1. Student interviews also provide corroborating evidence for classroom practices. This will be reported in the context of the achieved curriculum in Chapter 7.

6.2 Sample of the questionnaire survey

A total of 305 questionnaires were received, representing a return rate of about

30%, which is considered satisfactory. 53% of the respondents are males and 47% females. About 70% have been teaching for over six years and 31% are panel heads. Most respondents taught one (44%) or two classes (38%) in the year 2000/2001. The ratio of schools using Chinese as the medium of instruction (CMI) to those using English (EMI) is about 3:1, corresponding roughly to the proportion of these two types of school in Hong Kong.

6.3 Data from the teacher questionnaire

The data were analysed according to the five categories of response elicited from the teacher questionnaire as mentioned in Section 4.5.3: teachers' perceived curriculum, teachers' working curriculum, perceived constraints and opportunities, teachers' preparation and resource support, and teachers' evaluation of the new curriculum.

6.3.1 Teachers' perceived curriculum

Source of knowledge about the new curriculum

As indicated in Table 6.1, the syllabus and the textbook were perceived by respondents as the most important sources of information about the new curriculum. These were followed by teacher seminars and school panel meetings. The number of responses also indicates that most respondents drew information from more than one source.

Source Materials for understanding the curriculum	Perceived order of importance (in descending order) (%) N=305		
	First	Second	Third
Syllabus & Curriculum guide	35	34	16
Textbook	34	31	23
Teacher Seminars/workshops	24	21	23
I.S. Panel meetings of your school	12	19	20
Others – PGCE programme, textbook publishers, friends, colleagues, newspaper	-	-	-

Table 6.1: Teachers' perceived importance of different information sources for understanding the new curriculum

Differences between the new and old curriculum

Table 6.2 displays respondents' perceptions of the degree of difference between the old and new curriculum in relation to four curriculum aspects. Differences were the greatest in teaching approaches and approaches to practical work. Some difference was perceived in content knowledge. Assessment was the aspect perceived as least different, with 35% detecting little or no difference. These findings reflect that from the teachers' perceptive, the new curriculum was most distinctive in its teaching approaches and practical work, but not substantially different from the old one in assessment practice.

Area of the new curriculum	**Degree of perceived difference from the old curriculum (%)**		
	Great difference	**Some difference**	**Little or no difference**
Content knowledge (N=302)	7	84	9
Teaching approaches (N=302)	32	57	11
Ways in which practical work is conducted (N=301)	31	52	18
Methods of assessment (N=301)	11	54	35

Table 6.2: Teachers' perceived difference between the old and new curriculum

Table 6.3 shows teachers' perceptions of the distinctive features of the curriculum. Most respondents agreed that there were more contents worthy of learning, more everyday examples, more diversified teaching approaches, and more open investigation. Yet relatively less respondents agreed that greater emphasis was placed on the nature of science and the evolution of scientific knowledge These differential perceptions may reflect the degrees of emphasis on these aspects in the syllabus. The findings also suggest that the new textbooks were not quite up to teachers' expectation.

Perceived features of the new curriculum	**Extent of agreement by teachers (%)**			
	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
Topic areas/contents are worthy of learning (N=295)	5	79	15	<1
More everyday examples showing the relation of science with daily lives (N=298)	14	77	9	0
More emphasis on nature of science & evolution of science (N=293)	6	59	35	<1
Greater variety of teaching approaches (N=295)	11	75	14	0
More open investigation activities (N=296)	17	72	11	0
Encouraging teachers to adopt a more flexible approach to teaching rather than following rigid procedures (N=296)	11	66	22	<1
Better quality of textbook (N=294)	4	47	45	4

Table 6.3: Teachers' perceptions of the distinctive features of the new curriculum

6.3.2 Teachers' working/practised curriculum

Degree of change in teaching practices

Table 6.4, indicates that a majority of respondents reported some changes to their teaching practices in teaching contents, teaching approaches and practical work, while about 39% reported little or no difference in assessment methods. Table 6.5 shows that this degree of change correlated highly and positively with teachers' perceived changes in the curriculum reported in the previous section.

Aspects of teaching	Reported difference in teaching compared with the past (%)		
	Great difference	**Some difference**	**Little or no difference**
Subject knowledge taught (N=300)	7	82	11
Teaching approaches (N=299)	20	65	15
The ways that practical work was taught (N=298)	21	58	21
The ways that students are assessed (N=299)	8.4	53	39

Table 6.4: Teachers' reported degree of difference in teaching practices compared with the past

Correlation between teachers' perceived change in curriculum and change in implementation in respect of:	**Spearman rho**
Content	0.559**
Teaching approach	0.532**
Suggested practical activities	0.585**
Assessment	0.694**

** Correlation is significant at the 0.01 level (2-tailed).

Table 6.5: Correlation between teachers' perceived change in curriculum and reported change in their practices

This strong positive correlation seems to imply that if teachers perceived a change in the curriculum, there was a high probability that they would implement this in the classroom. Teachers in EMI schools reported a greater change in their teaching approaches compared with counterparts in CMI schools. The difference was found to be statistically significant ($p<0.05$) (Table.6.6).

Type of school	**N**	**Mean**	**t**	**df**	**Sig.(2-tailed)**
EMI	79	2.23	-3.22	134.52	0.001
CMI	218	1.98			

Table 6.6: Results of independent samples t-test to show difference between EMI and CMI schools in teachers' reported degree of change in teaching approaches

Implementation of investigative activities

Table 6.7, shows that 70% of respondents completed half or less than half of the investigative activities suggested in the syllabus but only 12% attempted all of them.

Coverage of investigative activities	Percentage of respondents (N=298)
None	8
Less than half	36
About half	26
More than half	17
All or almost all	12

Table 6.7: Teachers' reported coverage of investigative activities

The most significant reasons for not conducting investigations were, as shown in Table 6.8, "inadequate laboratory periods", "too time-consuming", and "class size is too big". Other less frequent reasons included "beyond students' ability", "inadequate equipment", "not meaningful", "inadequate language ability" and "avoiding discipline problems". The least frequent reason was "most of these activities are not included in our textbook". These data suggest that teachers' decisions depended mainly on structural or organizational factors rather than student factors or factors intrinsic to the nature of investigative activities. Since few teachers cited that these activities were not included in the textbook, there seemed to be a high degree of congruence between the syllabus and the textbook in the coverage of investigative activities.

Reasons for partial coverage or non-coverage of investigative activities	**Perceived order of importance (%) N=301**		
	1st	**2nd**	**3rd**
Insufficient laboratory periods	39	18	10
Too time consuming	30	21	7
Class size too big	15	18	17
Beyond pupil ability	10	7	9
Lack of adequate equipment	7	9	8
Inadequate language ability of students	7	5	7
Avoid discipline problems	6	9	9
Not included in our textbook	1	5	7
Too much content in the curriculum, insufficient time for coverage of all activities	2	<1	0
Not meaningful	6	7	8

Table 6.8: Reasons for partial coverage or non-coverage of investigative activities

Respondents were also surveyed on their strategies for teaching investigations. Table 6.9 shows that only 17% fulfilled the original intention to encourage students to perform open investigations. The majority provided close guidance to students. About a quarter even changed the format to teacher demonstrations. This indicates that teachers had a very strong tendency to modify this aspect of the curriculum to restrict the autonomy of students to test out their hypotheses and experimental designs.

Strategy adopted in teaching investigative activities	Percentage of teachers (N=297)
Students conduct most activities in small groups, under teachers' close guidance.	58
I demonstrate most activities, but involve the whole class in design.	24
I let students conduct most activities in small groups, providing minimal guidance.	17

Table 6.9: Strategies adopted in teaching investigations

Table 6.10 shows four main reasons why respondents provided close guidance in leading investigations, and these seemed to be related with each other. The perception that students lacked the ability to investigate seemed to be most important. The next three common reasons were, in descending order of frequency: avoiding discipline problems and confusion, reducing time required, and students' learning can benefit more in this way. Considering these reasons together, the results seemed to indicate that teachers were very much concerned about their efficiency in promoting learning in students, with minimal confusion created in the laboratory. Relatively speaking, there were much less concern about the lack of resources or students not possessing adequate language ability.

Reasons for providing close guidance to students during investigation	**Perceived order of importance (%) N=249**		
	1st	**2nd**	**3rd**
Student lack ability to investigate on their own	33	22	9
Avoid discipline problems or confusion in the laboratory	28	25	13
Can reduce time required	24	21	20
More beneficial to students	21	18	14
Not having enough apparatus or resources for open investigations	5	9	8
Students not processing adequate language ability	5	7	5
Others – there are just too many students			

The total percentage exceeds 100 for the 1st and 2nd rankings. This is because some respondents chose more than one item as their 1st or 2nd ranking.

Table 6.10: Reasons for providing close guidance to students during investigations

6.3.3 Perceived Constraints

Respondents were asked to describe freely what they perceived were the barriers to effective implementation. Most of the respondents provided some responses, implying that constraints were commonplace. As shown in Table.6.11, among the perceived barriers reported by respondents in implementing the new curriculum, organizational factors were most dominant, including lack of sufficient time, large class sizes, insufficient laboratory periods and lack of practical equipment. Student factors like poor abilities, motivation and discipline were also seen as important barriers. The new curriculum was perceived as unsuitable for the less able students. Students' language abilities were considered to be a barrier to a much greater extent in EMI schools than in CMI schools.

Barrier to effective implementation of the new curriculum	Frequency (N= 255)	
Organization		**200**
Not enough time	88	
Class size too large, too overcrowded, lack of space	54	
Insufficient laboratory periods	34	
Lack of equipment and space in the laboratory	24	
Students		69
Poor motivation, abilities too mixed, not suitable for less able students	34	
Discipline problems	15	
Inadequate language ability (English)	13	
Inadequate language ability (Chinese)	2	
Students are already occupied by project work in other subjects	5	
Curriculum content		47
Curriculum too lengthy, too many concepts covered, too theoretical, (need to use a more traditional approach), too few activities, over-emphasis on project learning, some investigation activities too simple	41	
Poorly quality of textbooks	6	
Teachers		30
Teachers not yet mastered the curriculum particularly the investigative approach	11	
Lack of commitment of teachers and team spirit in using new approach	10	
Teachers' excessive workload	9	
Assessment		
Difficulties in implementing new assessment methods, examination-oriented culture		9
School policy		
Over-emphasis on examination results and class discipline		6
Laboratory technicians		
Inadequate support and cooperation by laboratory technicians		4

Table 6.11: Teachers' perceived barriers in implementing the new curriculum

The comments targeting curriculum content showed teachers perceived this as lengthy and theoretical, and overloaded with concepts. This perception may act as a barrier to the adoption of the investigative approach. Many respondents also pointed out teachers' crucial role in the effective implementation of the curriculum. Some had yet to master the investigative approach. Concerns were also expressed about teachers' commitment, team working within a school, and how the already excessive workload could be managed. Difficulties in implementing the new assessment methods and the domination of the examination culture were voiced. Lack of increased support by laboratory technicians also presented a hurdle to some teachers. These constraints were interwoven as highlighted by the following comments:

> *"I could find no time to design teaching activities that are suitable for my students. (The activities found in the textbook are not completely suitable.) There are an excessive number of students in a class, and the teacher could not take care of them all. Investigative activities take time. The less able students are prone to be passive learners." (Organizational and student factors)*

> *"Conducting scientific investigations takes a lot of time, and this would seriously hamper teaching progress." (Organizational factors)*

> *"Most of the content still needs to be taught by a traditional approach. It is difficult for the new teaching approaches to be carried out on a wide scale." (Curriculum factor)*

> *"There are forty-two students in one class, this needs to be trimmed down by half. The curriculum content is sufficient, but investigation are very time-consuming. Students' language ability is inadequate, and they have problems in both speaking and writing." (Teacher in an EMI school) (Organizational, curriculum and student factors)*

> *"There are just too few periods for science. It is not enough to have only two laboratory periods in a week! Teachers' workload are so heavy that it is difficult to spend a lot of time to follow up the progress of each group of students (though it is very worthwhile). Not all colleagues in a school are equally committed. Students need to do project work in every subject. Their workload is so heavy that their interest has been reduced." (Organizational, teacher and student factors)*

6.3.4 Teachers' preparation and resources support

Training received by teachers and their perceived training needs

Over half of respondents felt inadequately prepared for implementing the new curriculum, and over 85% felt that further training was necessary. Only about 16% of respondents attended most or all of the training seminars organized by the CDI, and about one-fifth did not attend any of them. The most important reason cited for not attending was that they were too busy with teaching (Table 6.12). However, a significant proportion failed to attend seminars because they claimed to be unaware of them. This suggests that a more effective channel for disseminating information is needed.

Reasons for non attendance at teacher seminars	**Perceived order of importance (%)**		
	1st	**2nd**	**3rd**
I am too busy with teaching	49	25	2
The school was represented by other colleagues	28	29	5
I wasn't notified	22	11	17

Table 6.12: Reasons for non attendance of teacher seminars

For those teachers who attended the seminars, the majority found them useful in preparing for implementing the new curriculum. However, about one-third were either unsure about their value or found them not useful. Female teachers (Mean = 3.66) tended to perceive the seminars as more useful than their male counterparts (Mean = 3.44), a statistically significant difference, $t(258) = -2.321$, $p<0.05$.

Table. 6.13 shows that "familiarization with skills needed to teach scientific investigations" were perceived as the most important training need, followed by "familiarization with the process of science investigation" and the "use of non-conventional teaching strategies like group discussion and debates". The methods and skills in assessing students' process skills were placed at a lower priority compared with the previous ones. This supports the previous inference that assessment methods were the least emphasized aspect of the curriculum.

Training needs *Familiarization with...*	Perceived order of importance (%) N=241		
	1st	**2nd**	**3rd**
skills in leading students through scientific investigative activities	47	31	12
the process of scientific investigation	30	20	17
non-conventional teaching strategies/methods for teaching science, e.g. group discussion, debates, role-plays, projects, etc	24	26	20
new content/topics	12	8	9
methods and skills in assessing student's process skills	6	16	23

Table 6.13: Training needs perceived by teachers

Perceived self ability in teaching investigations

Most respondents expressed a reasonable degree of confidence to lead students through investigations (69%), though only 10% felt very confident. Those felt 'very unconfident' and 'rather unconfident' represented 1% and 20% respectively.

To identify whether teachers using different strategies to lead investigations exhibited different levels of confidence in implementing investigative activities, the data were subjected to ANOVA. But since the assumption of equality of variances was violated, Kruskal-Wallis Test, the non-parametric alternative, was used instead. The results show that those who adopted a more open-ended approach had higher self-confidence and the finding was statistically significant (Table 6.14). Such findings may imply that teachers expressing high confidence in teaching investigation tended to adopt more open approaches in leading investigations in class. However, no causal relationship can be confirmed because the results may also imply that teachers developed more confidence through adopting a more open approach. As teachers' self confidence was not related significantly to the coverage of investigative activities, it might not be as important a factor to influence teachers' decision to cover these activities as other organizational factors mentioned previously.

Teaching strategy adopted in investigative activities	N	Mean of perceived self confidence (4=very confident, 1=very unconfident)	Chi-Square	Df	Asymp. Sig.
Teachers' Demonstration	71	2.68	19.286	2	0.000
Close guidance by teachers	172	2.90			
Minimal guidance by teachers	51	3.16			

Table 6.14: Differences in self confidence among teachers adopting different strategies in teaching investigations

Further analysis using independent samples t test showed that teacher self-confidence also varied with gender. The difference, which was in favour of male teachers, was statistically significant (Mean for males = 2.96; Mean for females = 2.80, $p<0.05$). Another factor influencing teachers' confidence in leading investigation was their years of teaching experience. Teachers with more than 10 years' experience had higher confidence than their less experienced counterparts. Analysis using One-way ANOVA and multiple comparisons (Bonferroni statistics) indicates that the difference between teachers with 6-10 years of experience and those with over 10 years of experience was statistically significant (Table 6.15).

Years of teaching experience of teachers	N	Mean of perceived self confidence (4=very confident, 1=very unconfident)	df	F	Sig.
1-5 years	94	2.84	2	3.386	0.035
6-10 years	111	2.82*			
Over 11 years	99	3.01*			

**Confirmed by multiple comparison using Bonferroni test that the two means are statistically significant at the 0.05 level.*

Table 6.15: Differences in teachers' self-confidence in leading investigations by years of teaching experience

Perceived resource support

About 80% of respondents expressed the need for additional resources to implement the new curriculum, while 21% did not consider such a need. Table 6.16

displays the additional resources teachers suggested were needed.

Type of resource	Frequency N=178
Multimedia coursewares e.g. teaching materials in form of CD-ROMs and multimedia software, internet resources particularly those in Chinese, multimedia hardware in the laboratory	43
Reference books, worksheets and teacher guides e.g. reference books, worksheets, guidelines for practical activities in particular investigations, guidelines for teaching, teaching aids, newspaper cuttings, TV programmes, sample lesson plans, etc.	39
Additional equipment and apparatus	30
Small class size and more teachers, more human resources, including teaching assistants	31
Training for teachers e.g. training course, sharing sessions, workshops	25
More time for preparation of lessons	17
More teaching periods for science	14
More supporting staff for laboratory work e..g. a laboratory technician specially for the IS laboratory, hiring of laboratory assistants, etc	10
Training for laboratory technicians	2

Table 6.16: Additional resources needed by teachers to implement the new curriculum.

Multimedia resources were in greatest demand. There was also great demand for reference texts, worksheets and guidelines on investigations. This might indicate that teachers were not yet well prepared to implement the new curriculum, in particular the investigative approach. This inference was supported by the suggestion for more training opportunities for teachers. Teachers suggested a host of organizational resource including smaller class size, more human resources including extra staff, more preparation time and extra technical support. These, teachers believed, would assist effective implementation of the new curriculum.

6.3.5 Teachers' evaluation of the new curriculum

Teachers' perceptions of changes in students' attitudes

When respondents were asked to evaluate students' attitudes and motivation to learn science after the first year of implementation, about 54% felt that the change was positive. Around 41% perceived no change, while 3% felt that students' attitudes were more negative. This result could be considered as satisfactory given the fact that the curriculum was only implemented for the first time.

Respondents were asked to explain why they felt positive or negative. The reasons were categorized and displayed in Table 6.17.

Reason for positive change	**Frequency**	**Reason for no change or negative change**	**Frequency**
Student-centred and active learning	30	Students' lack of motivation to think	18
Development of thinking and communication skills	10	Lack of time	8
		Content cognitively too demanding	9
More relevant and interesting content	12		
		Learning and social environment not conducive to change	6
		Curriculum basically unchanged	6

Table 6.17: Reasons for teachers' perception of change to students' attitude and motivation with the implementation of the new curriculum

The most frequently cited reason for positive change was the adoption of a more student-centred and active learning approach. Respondents felt that there were more chances for students to participate and express themselves. Other attributes were improved content and the application of a scientific approach to problem solving. Those who were less affirmative felt that students' lack of motivation in study and reluctance to engage in thinking were endemic problems, which the new curriculum could do little to help. This could explain the high frequency of "no change" responses. Insufficient class time and too demanding content were also frequent. Teachers also felt that the learning environment including the examination oriented culture and the use of English as the medium of instruction, and the social environment of Hong Kong, were not compatible with the reform. Some perceived the new curriculum as similar to the old, reflecting a gap between the intended curriculum and teachers' perceived curriculum.

Further analysis of factors underlying teachers' perceptions of changes in students' attitudes toward the curriculum indicates that teachers' perceptions were moderately correlated with two other attributes (Table 6.18). These were "degree of changes in teaching practical science" and "teachers' self-confidence in leading investigations". These findings may imply that teachers, who changed their approach to practical or investigative activities under the new curriculum, or who had a higher self-confidence in leading investigative activities, perceived more positive students' responses. No causal relationship can be inferred from these statistics because these teachers may possess other characteristics that help to promote better attitudes among their students.

Correlation	Spearman rho
Perception of students' change in attitude and motivation * Changes in the way practical was taught	0.272**
Perception of students' change in attitude and motivation * Teachers' self confidence in leading investigative activities	0.253**

** Correlation is significant at the 0.01 level (2-tailed).

Table 6.18: Results of correlational analysis between teachers' perception of students' change in attitudes and two other attributes

Statistical analysis using independent samples t-test shows that teachers' perception of students' attitudinal changes varied across different types of schools. Teachers in CMI schools perceived more positive attitude change (M=3.58) than their counterparts in EMI schools (M=3.41), $t(295) = 2.246$, $p<0.05$. This may be because

CMI students were less inhibited by the language barrier than those in EMI schools, hence demonstrating better communication in investigation or other activities.

Perceived level of satisfaction with major curriculum areas

In all four curriculum areas including contents, teaching approaches, practical work and assessment, the respondents were satisfied with the new curriculum. The area of assessment generated least satisfaction (Table 6.19).

Areas of the new curriculum	**Perceived level of satisfaction (%)**			
	Very satisfied	**Quite satisfied**	**Quite unsatisfied**	**Very Unsatisfied**
Content knowledge (N=299)	3	84	12	1
Suggested teaching approaches (N=298)	4	82	14	<1
Suggested ways of investigation (N=299)	4	77	19	<1
Suggested methods of assessment (N=287)	1	74	25	<1

Table 6.19: Teachers' perceived level of satisfaction with major curriculum areas

The free responses provided by respondents show that many felt satisfied because the content was more relevant, rich and diversified. The teaching approaches were more thought-provoking, and the investigative approach effective in developing students' skills and attitudes. The assessment methods were diversified, covering a wide range of objectives . On the other hand, teachers felt dissatisfied due to excessive content, and content which was either too superficial or too difficult in certain areas. The investigations were considered too difficult for average ability students in terms of cognitive level and language demand. Guidelines for investigations were insufficient, and the results often unsatisfactory. Furthermore, there was a lack of time to cover all activities. For assessment, lack of guidelines proved to be the major issue. Some felt that the methods suggested were too time consuming, inefficient and difficult to implement. A few pointed out that the new assessment methods was incompatible with their school's policy which emphasized paper-and-pencil examinations. Others simply failed to detect any genuine change in assessment in the new curriculum.

Most worthwhile features of the new curriculum

Table 6.20 shows teachers' perceptions about the most worthwhile features of the new curriculum. The investigative approach was most popular because it generated thought-provoking independent learning and scientific attitudes among students. The second was the new content which was seen as relevant to everyday life, interesting and worthwhile. A more flexible and student-centred teaching approach was cited and linked to the investigative approach.

Worthwhile features	Frequency (N=245)
Investigative approach	
Provoke thinking, enhance independent learning, foster scientific attitudes, and a spirit of inquiry	79
Content	
Relate scientific knowledge to everyday lives	36
New topics are worthwhile, e.g. sex education, space	22
Interesting topics and activities, enhance students' interest in learning	14
Teaching approach	
Teaching approach greatly improved, more flexible	18
Student-centred, e.g. allowing students design their own experiments	8

Table 6.20 : Teachers' perceived worthwhile features of the new curriculum

As displayed in Table 6.21, the major perceived benefits of investigative activities for students were enhanced motivation and interest, development of scientific attitudes, and to a lesser extent, developing scientific minds. However, enhancing understanding of scientific knowledge and building of self-confidence, though emphasized by curriculum planners, were not perceived to be as important.

Perceived benefits of investigative activities	Perceived order of importance (%) N=301		
	1st	2nd	3rd
Enhancing motivation and interest	38	25	16
Fostering scientific attitudes	34	26	14
Developing scientific mind	22	18	18
Enhancing understanding of science knowledge	8	17	14
Building self-confidence & assurance of one's ability	8	15	14
No benefit	0	1	4

Table 6.21: Teachers' perceived benefits of investigative activities

Perception of improvement in comparison to the old curriculum

Table 6.22 indicates respondents' perception about whether the new curriculum would better fulfil its aims than the old curriculum.

Aims of new curriculum	Perceived level of agreement (%)				
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Acquire basic scientific knowledge and concepts for living in and contributing to a scientific and technological world (N=293)	4	52	37	7	<1
Develop the ability to enquire and to solve problems (N=292)	9	71	17	3	0
Learn science language and be equipped with communication skills (N=290)	2	50	38	10	0
Develop curiosity and interest in science (N=290)	11	66	19	4	0
Recognize the usefulness and limitations of science and the interactions between science, technology and society (N=292)	3	61	28	8	0
Make objective judgments or value judgments concerning science issues that impact on society based on knowledge and data (N=291)	3	45	43	9	<1
Appreciate and understand the evolutionary nature of scientific knowledge (N=291)	3	53	35	10	0

Table 6.22: Teachers' perceived degree of fulfillment of aims of the new curriculum compared with the old curriculum

Respondents seemed confident that the new curriculum could achieve some aims but not the others. Amongst those items that were rated highly are: "the ability to enquire and solve problems", "curiosity and interest in science", and "to recognize the usefulness and limitations of science and the interactions among science, technology and society". In comparison, those rated less favourably include "making objective judgments or value judgments concerning science issues that impact on society", "learning science language, acquiring basic scientific knowledge", and "appreciating and understanding the evolutionary nature of scientific knowledge".

Around 67% of respondents were convinced or totally convinced that the new curriculum was an improvement over the old one. Although 29% of teachers reported feeling "not sure", only less than 3% were unconvinced or totally unconvinced. Teachers tend to view the new curriculum more positively than the old curriculum.

The reasons for positive and negative responses mainly echoed those discussed earlier. Those feeling "not sure" felt that it took time to see the effect since both teachers and students needed to adapt to the new curriculum. They considered that there were both merits and demerits about the curriculum, and how it worked really depended on individual teachers and students.

Teachers' overall perception about the new curriculum yields some important correlations with other data. First, teachers' perception of improvement was related positively to both their perceived differences between the two curricula and the way they implemented the new curriculum (Table 6.23).

Correlation of teachers' perceived improvement with:	Spearman's rho
Subject knowledge (perceived)	0.095
Subject knowledge (practised)	0.179**
Teaching approaches (perceived)	0.174**
Teaching approaches (practised)	0.206**
Ways for teaching practical work (perceived)	0.184**
Ways for teaching practical work (practised)	0.259**
Methods of assessment (perceived)	0.213**
Methods of assessment (practised)	0.213**

** Correlation is significant at the 0.01 level (2-tailed).

Table 6.23: Correlation between teachers' perceived improvement and teachers' perceived difference between the two curricula

Although these correlations are from weak to moderate, they show that teachers who perceived a greater difference between the two curricula, and those who reported a greater difference in their own teaching practice, tended to perceive greater improvement in the new curriculum. In addition, the positive correlation of perceived improvement with perceived difference in the implemented curriculum was stronger than with perceived difference in the intended curriculum. This implies that teachers' actual practice was more important than their perception of change in influencing their perception of improvement.

Besides, teachers' perception of improvement was also related to their self-confidence in leading investigations, and to the medium of instruction. Teachers who were more confident in leading investigative activities tended to perceive a greater improvement in the curriculum (Spearman's rho = 0.127 at the level of 0.05 (2-tailed)). This finding is consistent with the one obtained earlier regarding the relation between teachers' self confidence and their perceived students' improvement in attitude and motivation to learn science. In line with the findings that CMI teachers perceived more positive attitude change than EMI teachers, CMI teachers (Mean = 3.74) also showed a greater tendency to view the new curriculum as an improvement than EMI teachers (Mean = 3.36), $t(297) = 2.712$, $p<0.05$).

6.3.6 Discussion

The survey findings show a considerable degree of alignment between the intended curriculum and teachers' perceived curriculum. Teachers generally agreed that the areas that best distinguished the new curriculum from the old were the teaching approaches and the approach to practical work (Table 6.2). Many teachers shared the views of the curriculum planners that the new topics areas were more worthy to learn and more relevant, particularly sex education; the teaching approaches were more diversified and flexible, and there were more open-ended investigations for fostering scientific attitudes and provoking thought (Table 6.3).

The findings underscore the importance of teachers' perceived curriculum as a bridge to implementation of the reform. Correlational analyses showed that teachers tended to change their teaching practices according to the change they perceived in the intended curriculum (Table 6.5). Yet there were gaps between teachers' perceptions and their practice. First, the intended emphasis on the nature of science and the evolution of science has not been carried through adequately to teachers (Table 6.3). Second, many teachers did not seem to realize the suggestions about changes in assessment approaches (Table 6.2). In fact, these gaps may reflect the inadequacy of the intended curriculum as discussed in Section 5.3.5.

Third, there were gaps in the coverage of investigative activities (Table 6.7) and in the way investigations were taught between the intended and implemented curricula (Table 6.9). Although teachers generally perceived the investigative approach as the most distinctive feature of the curriculum, the coverage of investigations seemed to fall below expectation. The relatively low coverage was attributable to organizational factors, like inadequate laboratory periods, large class size, lack of curriculum time and heavy content (Table 6.8).

Even when investigations were conducted, teachers tended to adopt close-ended approach in leading students through the process. Such changes seem to base largely on pedagogical and management considerations. The perceived lack of student ability, avoidance of confusion or discipline problems, and the tendency to use time efficiently to maximize the "benefits" to students (Table 6.10) all led to distortion of the nature of investigations. Teachers generally did not perceive the development of students' self-confidence and self-assurance as an important purpose of investigations (Table 6.21). This seemed to be inconsistent with the intentions of the curriculum planners who hoped to build up students' self-confidence in the investigation process.

The main constraints teachers perceived fell into four types: organizational factors, like large class size and lack of laboratory periods; student factors like lack of ability in students; curriculum factors like lengthy content; and teacher factors like insufficient mastery of the new curriculum and its teaching approaches. Over half of teachers considered they were inadequately prepared for implementing the new curriculum. About one-fifth was rather unconfident of leading investigative activities. Training needs were identified as the skills to lead scientific investigations, knowledge of the investigation process itself, and the use of non-conventional teaching strategies (Table 6.13). Some teachers missed the training opportunities because they were not aware of them (Table 6.12). Besides, evidence seems to suggest that female teachers and less experienced teachers were less confident in leading investigations than their male and more experienced counterparts. Some teachers viewed the continued adoption of traditional approaches as rooted in the examination-oriented culture in schools.

Despite these constraints, teachers were positive about the potential for success of the new curriculum in comparison with the old one. They were largely satisfied in general terms with the new curriculum. However, many were unsure whether the new curriculum could enhance students' motivation and attitude toward science though more were convinced that the new curriculum was an improvement over the old one than those who were not (Table 6.22). Despite the fact that EMI teachers reported a greater change in implementation, CMI teachers tended to evaluate the curriculum more positively with regard to students' change in attitude and motivation and in the degree of overall improvement as a result of the new curriculum. This finding seems to support the planners' assumption that using Chinese as the medium of instruction can facilitate teaching and learning of the new curriculum.

The survey findings also indicated that teachers' perceived changes in their own practices were positively related to their perception of improvement of the curriculum (Table 6.23). As discussed previously, teachers' reported degree of change in practices was also positively related to their perceived change in the curriculum. Possibly, it could be inferred that teachers perceiving greater changes in the curriculum have a deeper understanding of the reform, and hence, exhibiting a greater tendency to change their practice. As a result, they are more likely to perceive improvements over the old curriculum.

6.4 Data from the teacher interviews

Two rounds of interviews were conducted with the teachers participating in the quasi-experimental study. The first interview took place mid-way through the first year of the new course, and the second at the beginning of the following academic year. This section reports data from both interviews except for teachers' comments on students' performance which will be reported in Section 7.4 in the next chapter.

The four teachers interviewed are Ching (School 1), Yan (School 2). Fong (School 3) and Keung (School 4) (all names are pseudonyms). The background characteristics of these four schools have already described in Section 4.5.3 of Chapter 4. All schools used the same textbook except School 4. The quotes from the teachers are from the first interviews unless otherwise stated.

6.4.1 School 1 - Ching

Ching was a female teacher teaching in School 1. She had taught I.S. and Biology for nearly eight years. Her class had two double laboratory periods and one single classroom period for each six-day cycle.

Perceptions of the new curriculum and science learning

Ching learnt about the new curriculum through attending seminars run by the CDI. She seemed to have a very clear understanding of the new curriculum, which she saw as emphasizing the investigative approach. This is her description of the curriculum.

> *"It enables students to gain experience in doing experiments. It also intends to introduce the concept of variables; how variables are dependent on one another; what variables need to be controlled; how to present experimental data; what procedures they have to pay attention to in order to obtain results; how to draw*

conclusions and whether the conclusion matches with the principles they learnt in class."

Ching perceived the new curriculum as similar to the old one in terms of knowledge, yet she saw a greater link of scientific concepts to everyday life as evidenced by the inclusion of topics that explicitly relate traditional science to everyday living. She considered that the main difference was in the approach. Teachers were no longer expected to use exposition, but to guide students to think. The investigative approach introduced in the first chapter was meant to be revisited in subsequent chapters. She noticed that there were also more instances for students to read articles and search for information themselves. Ching expressed these views about the role of the teacher in the new curriculum.

> *"She has to create an environment in which students could really learn. In doing so, she may have to raise questions, act as a consultant for giving advice to students and answer their questions, e.g. in designing experiments. At times, students would need your verification, then you have to provide knowledge. You have also to tell them what resources they have to look up. In the old days, you could do all the talking yourself though you still needed to control class discipline."*

Ching saw enjoyment and scientific attitudes as the two most important things to be learnt from science, which she conveyed in the following comments.

> *"Enjoyment... for it can motivate students to learn especially for junior form students... Next is discipline in science, including attitudes and behaviours, e.g. being serious, meticulous, rational and careful in handling apparatus. He will read up books and form his own views, which are supported by evidence. I think these are all some forms of discipline."*

Ching agreed that doing experiments and reading up for information were two important ways to learn science. "Both guided and open-ended investigative experiments are necessary. Guided discovery allows students to verify things quickly. It is a kind of exposition but students are to discover by themselves," she said.. She thought that it was not always necessary to investigate every detail, which may be quite elusive. Students should gain some basic concepts first before carrying out further investigation. She considered reading as another important way to learn science.

Implemented practices

According to Ching, the curriculum reform was a healthy change. She expressed that the old approach could easily be degraded to the transmission of knowledge from the textbook, with the nature of science forgotten. Now, teachers become more aware that they should emphasize investigation. Despite her support for the new curriculum, she doubted whether this was suitable for her 'average ability' students. Her concern for student ability seemed to be paramount in her choice of textbook, student activities, and the ways students were led through investigations. For example:

> *"We did make an effort in selecting a suitable textbook. We found that some textbooks emphasized investigation but lacking in sufficient subject content. For our students, in order to ensure that they received sufficient knowledge input, we chose a more conservative one, one that is easy to read and with sufficient content to provide students with a good knowledge base. We can then be sure that the textbook will not lead to problems. The activities may not be that open-ended, but we treat the textbook mainly as a resource book for learning... There are others that offer more open-ended activities, but they tend to provide less information."*

Ching took the Unit "Wonderful Solvents" as an example to illustrate how she selected student activities.

"I asked students to take water samples to the class to find out whether there were impurities. But I didn't let them design filtering devices because it would be too difficult for them."

In leading students through an investigation, Ching adopted a guided approach reminiscent of guided discovery as she feared that students might experience difficulties if they were left on their own.

"My practice is to tell them what to look for in an investigation so as to turn abstract to concrete, then see how the variables can be measured and under what circumstances will the variables changes. If there are factors affecting it, what factors should be kept constant. I will ask them to suggest, and then I will supplement in case of omission."

In response to the new curriculum, Ching and her colleagues have extended the assessment to cover practical and investigation skills.

"Apart from written tests, we also assess students ' practical skills, e.g. preparation of microscopic slides. I would check whether their specimens were in focus and whether their preparations were messy or not. If they carry out investigation in class, after collecting data, I will check their setups and see how they explain their data. For searching of information through the Net, I would ask students to present their findings before the class and assessed their performance in presentation. The practical assessment was also counted toward student total score."

Factors affecting implementation and perceived changes in students

After going through the new curriculum, Ching expected that her students would become more familiar with concepts like independent, dependent and control variables. Students might become accustomed to analyzing experiments in those terms. There should also be an increase in their awareness of social problems, which were not mentioned, in the old curriculum. For laboratory skills and interest in science, she thought the effects of the two curricula were basically similar.

Overall speaking, Ching commented that the new curriculum was ambitious. She felt that the new curriculum caters best for very good students, and the investigative approach was ideal if the class size was not that large and if there was sufficient equipment. She thought that there should be alternative syllabuses for students with different abilities, as the content of the present curriculum was too rich that it was difficult to make a choice on what to teach.

Apart from student ability, Ching regarded the teacher as crucial for the successful implementation of the new curriculum.

"The teacher has to be resourceful enough... because in leading students through the investigative process, he has to be flexible. He has to know the subtle changes involved in experiments to order to lead the investigation more effectively.... In fact, we could not rely on one teacher ' s effort. It really depends on the collegiality of all teachers. The support from technicians is also very important because there are many activities needed to be tried out. We are fortunate to have a very good team of teaching and technical staff."

Support for teachers

For Ching, teacher seminars, rather than textbooks, were the most important channel for her to obtain a clear direction of the reform. She said:

"Reading the textbook alone would not give a clear sense of direction. This was because the textbook may only supplement the old curriculum with new experiments to cater for the need of the new curriculum. If the teacher does not understand the aims of the investigation, she may teach every procedure to the students before they start doing it. A lot of important messages were discussed during the seminars. If the teacher did not attend them, they were likely to teach in the old way."

In addition to the training seminars, Ching said she needed more support in form of experience sharing sessions, newsletter on teaching of the new curriculum, and more Internet resources. She thought that more resources in Chinese were needed to support teaching in the mother tongue.

Reflections on the first year of implementation

In the second interview, Ching talked about her own analysis as to the merits or demerits of the new curriculum and what changes she would like to see in her own teaching in the future:-

> *"The biggest merit is that it could create doubts in students..., 'cognitive dissonance' is the term that I could recall to describe it. The curriculum could arouse interest of students since it is related more to their daily lives. I think, at least, students would find science a subject that they are able to control."(2nd interview)*

She went on to elaborate what she would do next.

> *" Now we have stimulated students to think and to learn the method.. it is time to put greater emphasis on written work, say, on recording and report writing.. But the difficulty is that we are constrained by the intake of students, I believe that in those schools which take in more able students, their students would be more ready to write out what they think. For our students, it is much more difficult to develop both their content knowledge and writing skills at the same time. Particularly, when such kind of writing is not being assessed at present."(2nd interview)*

When asked whether she would like to go further in changing the way of assessing students, Ching became more hesitant.

> *"I think we need to proceed step by step. This is something related to culture and*

beliefs. Moreover, the traditional type of assessment is more objective." (2nd interview)

6.4.2 School 2 - Yan

Yan was also an experienced junior secondary science teacher, having taught for about ten years. Apart from science, she also taught Biology. Her class has only one double laboratory period and two single classroom periods per seven-day cycle.

Perceptions of new curriculum and science learning

Her knowledge and understanding about the new curriculum was derived mainly from the textbook as she had not attended any teacher seminars or read the syllabus. Yan said that the content of the new curriculum was similar to the old one except that the former was more lively, for example, there are more contents relating to health. As for the teaching approaches, she noticed that there were more activities for students and more guidelines for carrying these out. She disagreed that the emphasis on scientific investigation was a significant difference between the new and the old curriculum, as reflected in the following dialogue.

I:	*The new syllabus appears to place more emphasis on investigation than previously. Do you agree or do you notice that difference?*
Yan:	*It really depends on how the teacher present them. I think if time allows, investigation is possible, It was also feasible in the past.*
I:	*Do you think the presentation of "investigation" is different in the two syllabus apart from the different interpretation by teachers?*
Yan:	*There is no big difference. I think they are more or less the same."*

However, when Yan was asked what she considered as the main objective of the new curriculum, she replied:

"Training of the scientific mind. It goes further along the investigative approach than in the old curriculum that required students to follow instructions closely. It was just like feeding to students in the past. The new curriculum tries to promote scientific thinking and I think students' interest will be promoted if these activities are conducted as intended. I think they are better."

Yan agreed that acquiring a scientific mind was important to students. Letting students find out the solution of problems before telling them the conclusion beforehand is preferred.

Implemented practices

Despite her understanding of the new curriculum and her belief in science learning, Yan said the activities she covered were mainly those already existed in the old curriculum. She rarely asked students to conduct investigative activities, which she considered as "extra" activities.

I:	*Did you conduct this one (an investigative activity in Unit One) with your students?*
Yan:	*Not this one. We usually ask students to do experiments in laboratory periods. This activity is an extra one. We only asked students to do extra activities that involved them in collecting additional data. It would be difficult to arrange students to do these sort of [investigative] activities in laboratory periods. But these activities are good because they can train students to have a scientific mind."*
I:	*And what about these activities [other investigative activities in Unit One]?*
Yan:	*We seldom did these, only when enough time was available. I would talk through some with students. It is just impossible to conduct all these activities. Just impossible. Our schedule is too tight. These are all additional activities not found in the old curriculum. The previous activities were not trimmed down but new activities were added."*

As she perceived that investigative activities weren't possible in her case, the only additional activities she allowed students to do are those that could be conducted by students outside school hours, like researching information or collecting materials on certain themes. For the same reason, Yan seldom used other less conventional teaching approaches as suggested by the syllabus, like project work, role-plays or debates.

In doing practical work, Yan said she would provide a certain degree of guidance to help students through experiments. But she said it would depend on the ability of the class. She would provide more able classes with fewer guidelines The reverse was true for weaker classes. Her other consideration was the level of difficulty of the activity. If it were difficult, she would do the thinking on behalf of her students.

Factors affecting implementation and perceived changes in students

Yan regarded the lack of time as the chief reason for deviating from the intended practice. She said her school used to have five periods in a seven-day cycle. But after switching to the use of Chinese as the medium of instruction, the number of periods was reduced to four because learning in Chinese was considered to make science easier for students. Yan suggested that one period would normally used for watching Educational Television programmes or completing class work (exercises), so there were not many periods left.

Yan noticed that students participated actively and that they were generally positive to new themes like sex education. She considered that students liked both past and present curricula, so she didn't notice a change in interest level because of the new curriculum. When asked what changes she might make to her teaching practice, she said she would consider providing more open-ended activities for students, or asking them to bring back to the class materials for testing, and comparing their results with other groups. She considered that this was possible only if time was available, but it would be difficult to do this very often.

Support for teachers

As Yan was not well aware of the support provided by the CDI to teachers regarding the implementation of the new curriculum. She didn't know much about what have been done, including the teacher seminar. She said maybe their panel head had participated in them, but exchanges between the panel head and members of the panel were not frequent. She said that she couldn't spare much time in junior secondary science because she had many other subjects to teach. Despite this, Yan said she had adequate support from publishers which provide plentiful teaching resources.

Reflections on the first year of implementation

From the second interview, there was little change in Yan's perception and practices. She still had reservations about allowing students to conduct open types of investigation unaided. She preferred to discuss with students so that they could come up with a unified plan before starting the investigation. This allow her to have all the equipment and materials arranged beforehand. She was much concerned about discipline and safety problem:

> *"I would have a discussion with them [students] first. It may not be possible to adopt their ideas. This is also because I need to take out all the apparatus beforehand. Moreover, we don't have enough apparatus. Time is not enough. Human is also a factor (There is only one teacher). Some situations are dangerous, especially when fire is used. Remember I have forty-one students in my class."*

Despite these, Yan considered the curriculum as more flexible, more interactive, more relevant, and less boring than the old version.

6.4.3 School 3 - Fong

Fong was teaching in School 3. She has been teaching I.S. for 10 years. Her major subject is junior secondary science. Her Secondary 1 class has one double laboratory periods and two single periods per six-day cycle.

Perception of the new curriculum and science learning

Fong was aware of the new curriculum as soon as the syllabus was available. Like Ching, she attended most of the teacher seminars. She regarded the increased relevance of contents to daily lives and the concepts of investigation as two major diversion from the old curriculum. Yet she perceived that the guided discovery approach characteristic of the old curriculum still persisted in the new curriculum and there were only a few investigative activities that required students to think through.

Fong considered it most important for students to acquire the basic knowledge to help them to solve daily life problems. When asked whether knowledge or processes was more important, she became more ambivalent in her answer:-

" If there is no examination, I think processes are important than knowledge, but with examinations in place, knowledge is more important to students. "

Implemented practices

Fong's contradictory, yet pragmatic, view might explain her tendency to adopt a guided discovery approach. She explained that an open-ended approach was less effective in helping students to develop knowledge. Like Ching, she agreed that designing experiments was most difficult for her students. Hence, she would tailor the activities to suit the level of her students.

> *"I would allow the better class to do that (an investigation for testing which plastic bag is stronger) but not the weaker class... For the better class, I gave them two bags and I would allow them to design."*

For assessment, Fong said they had an end-of-term practical test. Yet, the emphasis of the test was on practical skills, say the use of Bunsen burner, rather than on process skills. Although she would assess her students on their performance of investigative activities but the results were not counted toward the total score.

Factors affecting implementation and perceived changes in students

Apart from students' lack of ability, Fong felt that time and class size were two other important constraints for conducting investigations.

> *"We haven't gone through the investigations on filtering mainly because of the lack of time since they are time-consuming... We've got only four periods in a six-day cycle, which include two single classroom periods and one double laboratory period for activities. We only have one teacher to attend to the whole class, which is so large. But I don't think these problems can be solved."*

Fong complained that the new textbook they used did not provide as sufficient knowledge as suggested by the syllabus. Despite this, she still commended the new curriculum as being able to generate better responses from her students because it was more relevant to their daily lives, so that students could apply what they learned in everyday contexts.

Support for teachers

Like Ching, Fong agreed that the teacher seminars, which she attended, were useful and sufficient but she did not agreed that what she was told in the seminars could necessarily apply in the classroom, The main reason was insufficient time to implement the activities. She wanted to see more teaching resources provided to teachers like multimedia aids in form of CD-ROMs, question banks and more investigative activities that they could choose from.

Reflections after the first year of implementation

After teaching for a year, Fong appeared to be much more spontaneous in expressing her feelings toward the curriculum. Her reflections in the second interview were:-

> *"I have the feeling that the new curriculum is not substantially different from the old one in terms of content. But students could learn more by going through all these activities. They won't get much benefit by merely listening. The implementation of these activities requires both curriculum time and the commitment of the teacher in finding relevant information……You know, we need to spend time teaching students those terms in English as well. We have to ask students to dictate English terms and that uses up time." (2nd interview)*

As for the changes in student performance when compared to the old curriculum, Fong felt that students had more interest in learning science but there was not an obvious change in science skills.

> *"I only noticed that they were less frightened in doing experiments, but I am not sure that they are better than those in the old curriculum." (2nd interview)*

On the changes she would like to make in the coming year, Fong said:-

"I would cut down on the time for discussion, and teach important concepts through exposition so as to ensure that they could grasp those concepts, and I would also try to conduct more experimental activities. I think I would add more varieties to the assessment, probably assessment of process skills... But if such is the case, cooperation among colleagues has to be strengthened as all teachers need to be involved in assessing students." (2^{nd} interview)

6.4.4 School 4 - Keung

Keung has taught I.S. for about 15 years. He also taught Physics in upper secondary years. His class has three laboratory periods and two classroom periods per 6-day cycle.

Perception of the new curriculum and science learning

Keung did not attend any of the I.S. teacher seminars. His knowledge about the new curriculum was mainly from his Panel Head and the textbook. He saw the focus of the curriculum as allowing more discussion among students, and more thinking about problems. To him, the contents were similar in both the new and old curriculum, yet he agreed that the new curriculum encouraged students to play a more active role than previously. Students were supposed to discuss problems among themselves, to learn sometimes through simulation activities, like simulating the transmission of sexual diseases. He considered problem-solving as the most important thing to learn from science. He said science was a set of methods including observation, analysis and making inferences.

Implemented practices

Despite all these constraints that Keung perceived, he did make attempts to implement the curriculum he saw feasible.

"... I have asked students to look up from magazines or books in our library any science topics they felt interested and to make a report. We have done that once in the first term. It's quite a symbolic kind of work. They made a photocopy of the article and they wrote out some questions about it and provided with answers as well. So the questions were asked and answered both by themselves."

Obviously, the time constraint was an important concern of Keung. He said that he would do activities that were less time consuming, as time was not sufficient. For instance, he would rather conduct a discussion rather than a debate.

Keung had not conducted any investigative activities suggested by the textbook by the time of the first interview. For instance, in the activity to investigate the effect of the size of the air hole on the hotness of the Bunsen flame, he just mentioned to students that opening the air hole would result in a hotter but a less bright flame, and vice versa when the air hole was closed. There seemed to be little change in the way Keung led students through experiments. The old guided discovery approach still prevailed:-

"I wouldn't give autonomy to students. I didn't let them decide what to do….."

"I would explain every procedure. Before splitting into groups, I would ask them to come out to try out the procedure first. This is because Bunsen burner was often used, so I worry that they might run into accidents. As a result, I have to be satisfied with less autonomy and less creativity on the part of the students. I would ask some students to try out in front of me and the class before allowing them to conduct the experiments in groups. I would usually select those students who are likely to run into trouble for trying out to make sure they know how to do it."

Keung elaborated the need to have more control and less autonomy for students.

"You don't have much control with such a big class. Moreover, the equipment isn't sufficient. I have eleven groups, with four in each, except for the last group, which has three. We have only ten sets of apparatus. So the three students in the last group had to be divided up to join three other groups in one lesson, and another three groups in the next."

As for assessment, in Keung's view adjustment has been made only to the content rather than to the process skills

"We did incorporate questions that reflect the new content like questions that require students to discuss, say, what are the requirements of parents? We expect answers like being physiologically mature, being able to earn a livelihood, and prepared to sacrifice. In the past we did not have that kind of items..... We haven't attempted to include tests or items on investigations. We have questions just similar to those we have previously. We would set questions that students have a higher chance of answering correctly... We need to be fair on top of others, so when we come to end-of-term examination, we tend to be much more conservative and revert to conventional type of questions like true-or-false, matching, etc."

Keung elaborated the reasons for his following a more conventional mode of assessment.

"We don't know what the future direction is. If we follow what we have been doing, students will have an advantage when they proceed to higher forms with similar types of examination, like the certificate examination. Whether a student is regarded as good is determined by what he scores in the certificate examination, not how creative he is. Students may be regarded as foolish if they provide very creative but wrong answers."

Factors affecting implementation and perceived changes in students

Keung looked pessimistic about the effectiveness of adopting the new approaches. He said:-

"Now theoretically speaking, students can discuss problems among themselves. And they can learn through simulations like putting white dust powder on their hands and see how many students got the dust on their hands eventually. This is to simulate the transmission of sexual diseases. But it seems that I can't teach while doing such activities. I may look like a fossil that is not being receptive to new things. Another activity is to make a model for estimating the timing of the menstrual period, but nobody handed in the model to me. This is probably because we didn't want to put too much pressure on them. They have to face the same number of examinations, which would not change any way. Unless we change the examination to take into account other achievements, things will change but we didn't go that far for the time being."

This pessimistic stance is repeatedly expressed throughout the first interview.

"I think what the new curriculum suggests is good because they want to see that students work like a scientist and not to provide students with the answer right at the beginning. Many of the questions are open-ended in order to stimulate thinking. That's good. But we don't have that kind of environment. Just consider the present scenario, with a class size of 43, the same spoon-feeding approach, the same assessment with fill-in-the-blanks and true/false questions, the new approach is difficult to implement. In our case, we have to adhere closely to the schedule. There is regular checking of student assignments by the school, and you've to explain if you can't work according to the schedule. So you have to keep a constant eye on the time-table. We couldn't use the new approach because of all these constraints."

Although Keung realized that the intention of the reform was good, he raised doubts as to the actual impact of the curriculum.

"It is good, but everybody should know where the core of the problem lies. Since

we could not reduce the number of students, it is very difficult to teach in the way the curriculum recommends. I think what is important about the curriculum is to let students think and innovate, and to pose questions, but we all along emphasize examination, and these new requirements will not be assessed.... It is good to let students think out answers to questions. But the teacher must have a lot of patience and does not need to prepare students for a tight schedule of tests. If the teacher need to meet a tight schedule, he has to teach quickly, Then he is likely to revert to the traditional approach. "

Concerning his students' responses, Keung said they were more or less the same when compared with the old curriculum. He considered that responses were determined by the teacher, not the curriculum. Even if the curriculum was very boring, good preparation and interesting and lively examples could make students feel more interested.

Keung agreed that the textbook did attempt to provide more activities for students, and with discussion topics to stimulate them to answer questions, which was different from the old textbooks. The old textbooks include few reading materials and were not connected to daily life. But he thought that the new textbook could still improve to meet curriculum intentions.

When asked whether he would consider making changes in the second half of the year, he said:-

"Not much. As I have been teaching for so many years, I would more or less stick to a particular way of teaching. But I will try to follow the book and pose questions to students to stimulate their thinking."

Support for teachers

In response to what was lacking and needed to be provided to the teachers, Keung's comment was consistent with his perception so far.

> *"I think it is not a problem of resources, but rather class size. In our case, students have to use the water tap on the teacher's bench."*

Reflections after the first year of implementation

When asked in the second interview whether there was any improvement in student performance under the new curriculum, Keung replied: -

> *"I didn't notice an obvious change. Even when we set the examination paper in Chinese, students didn't answer the questions well. Say, for example, we asked them to predict what they would observe when an ice cube was left from a few minutes to a few days, and then to explain why this occurs. A lot simply wrote that the ice melted into water, and left the second part blank. They seemed to have difficulties even in distinguishing between observation and interpretation... As for skills and attitudes, I think they were more or less the same as in the past. Students still had to follow the old rules in the laboratory, except that there were more readings and more materials in their textbook." (2nd interview)*

Keung showed little change in his perceptions and views about the new curriculum and how he would implement it. He envisaged few changes in his intended teaching pattern for the second year. He reiterated the constraints like class size, examination-oriented curriculum, discipline and safety problems. Keung talked further about how he was going to teach in the coming year:-

> *"I think there won't be great changes in the teaching of science. I would split, as I often do, big concepts into smaller parts, with questioning to lead students to a*

more complete understanding of these concepts. Say, when a sugar solution gets smaller in volume, what has disappeared? Why do you think water has disappeared but not sugar? How to prove it? I think every teacher would teach like this. But as you said, the new curriculum emphasized students investigating by themselves, like designing experiments, we did relatively little because of all these constraints. Moreover, I am not accustomed to this way of teaching. Perhaps I don't have confidence in my students. I always have the worry that students would break glassware, fooling around in the laboratory and get hurt. It doesn't matter that much if students fail to learn a particular part of the lesson. But if these things occur very often, they will surely get me into trouble." (2nd interview)

However, with the increased multimedia facilities available, Keung said he would make greater use of computer-simulated experiments and games to teach students to avoid the above problems.

6.4.5 Discussion

The portrayals of the four teacher interviewees reflect both unity and diversity as to how the intended curriculum was implemented in their classes. The four teachers were generally aware of the overall emphasis of the new curriculum. They exhibited different degrees of understanding about the specific areas of the curriculum, and attached different importance to them. Their perceptions and understanding of the reform seems to be a variable of the kind of input they received. Ching's understanding of the curriculum was the most thorough of all. She saw the development of the investigative approach and the relevant process skills as the most important aim of the new curriculum, Fong was also well-informed though not to the same degree as Ching. The relevance of the new contents of the curriculum struck Fong most forcibly. She perceived that the new curriculum was still dominated by guided discovery, rather than open investigations. Keung considered the new curriculum as more thought provoking than the old one, which aimed to teach students to be more active problem-solvers. By contrast, Yan was less sure of the intention of the new curriculum. Though she saw the intention as training of the scientific mind, she doubted whether the new curriculum would make any real difference as she considered that with enough time available, the old curriculum could also serve this purpose.

The four teachers also exhibited differences in their perceptions of difficulties in implementing the curriculum. The four interviewees to a certain extent perceived the new curriculum as suitable for more-able students. Ching regarded the skills and expertise of individual teachers and collegiality of the whole teaching team as important factors for realizing the spirit of the new approach. Fong felt a strong pressure from the new curriculum as it demanded more preparation work from the teacher. She was preoccupied with the concern to equip students with sufficient knowledge for the examination, which led her to de-emphasize process skills. By contrast, Keung saw the obstacle to authentic implementation as an organizational and a cultural one, related not only to the school but also to society at large. To him, the core of the problems lay not only in the large class size, and the tight and inflexible teaching schedule, but also in the examination-oriented school culture. All these contributed to the perpetuation of the spoon-feeding approach. He perceived all these as impenetrable barriers not amenable to change. For Yan, the greatest concern was insufficient teaching periods, which happened to be the fewest amongst the four schools.

The concerns of the four teachers explain their differential practices in implementing the new curriculum. Ching had made an effort to enable her students to grasp process skills through her guidance in experimental or investigative work. She and her colleagues were committed to implementing the new curriculum as shown by their introducing a new mode of assessment focusing on students' process and practical skills. Fong had tried to tailor investigative activities to suit the level of her students, adopting a guided approach in leading them to investigate as time would allow. Similar to Ching's, Fong's school also introduced a practical test, yet focused on laboratory skills instead of the science processes required for an investigation. Compared with Ching and Fong, the degree of implementation was much more limited in the classes of Keung and Yan. This was attributed to organizational barriers which they perceived as not amenable to change. Keung relied mainly on the use of verbal discussion and project work rather than student-directed open-ended investigation to engage students in thinking and problem solving. Whereas in Yan's class, the lack of teaching time had caused her to stick closely to the old practice, and to rule out the possibility for allowing even a single open-ended investigation in her lessons. Her new practice was mainly confined to the engagement of students in gathering information outside school hours. Both Keung and Yan did not intend to change their assessment practices but to adhere to the traditional paper-and-pencil test.

With the implementation of the new curriculum, all four teachers perceived some, if limited, improvement in students' learning. Ching agreed that the new curriculum could provide a challenge for their students to think and arouse their interest. Fong felt that her students showed more interest in learning science because of increased relevance to their daily lives, but she observed no obvious improvement in process skills. Keung saw little obvious change in both process skills and attitudes as the old practices still prevailed. Yan perceived some improvement in student participation and an increase in students' interest in learning particular topics.

The interviewees suggested that in the following year, they would cover more investigative work. Yet, it is difficult to determine whether they were influenced by the experience they gained in the first year of implementation or by the findings of the quasi-experimental study. The changes mentioned includes developing students' report writing skills (Ching), providing more opportunities for students to conduct open-ended investigation or experimental activities, and expanding the practical test to cover process skills (Fong), and increasing students' participation in computer-simulated activities (Keung). However, these teachers expressed reservations about the extent of changes given the constraints they mentioned.

The interviews seem to indicate that teachers who possessed better knowledge of the new curriculum and with greater commitment to the reform were more likely to change their practices and implement the new curriculum than those who received very little or no training. Ching could be considered as most well adapted to the new curriculum and Keung and Yan the least well adapted.

6.5 Summary

The survey data and findings of the teacher interviews concur with each other. In response to Sub-question 2.1, teachers' perceptions were generally in line with that of the curriculum planners, except perhaps for assessment practices. The least change perceived by teachers was assessment practices. This corroborates the findings of the documentary analysis that this aspect has the least clarity. The interview portrayals indicate that teachers' perceptions seemed to be determined at least partly by the source of input about the new curriculum.

In response to Sub-question 2.2, both the survey and interview findings show that teachers tended to change their practices in accordance with their perceptions. Both sets of data concur that a major deviation from the intended curriculum was the incomplete coverage of investigations and the distortion of the nature of these activities. These were largely due to school organizational factors, and teachers' concern about students about student ability, discipline problems, time constraints and the benefits for students. The interview data shows further that teachers' attitudes and commitment, and their knowledge and skills are all important variables in bringing about changes in practice.

In response to Sub-question 2.3, the opportunities are that the reform was in general well perceived by teachers as an improvement over the new curriculum. The new approaches and content were considered worthwhile. Those who understood its aims were more likely to change their practices and to perceive improvements. Teachers in CMI schools evaluated the achieved curriculum more positively than EMI teachers, indicating that mother-tongue teaching was probably more advantageous for the implementation of the new curriculum. Furthermore, training provided by the CDI was regarded as useful. Many teachers conceded they needed training in leading students to carry out investigations, indicating that teacher training may improve the adoption of the investigative approach.

The major constraints teachers encountered were, in order of importance, related to school organization, students, the curriculum and teachers. These constraints have jeopardized the chances of using a genuine open-ended investigative approach. There were suggestions from teachers that all these factors may be rooted in the examination-oriented culture in Hong Kong schools, and in Chinese culture which emphasizes obedience to authority.

The findings discussed in this chapter are a mixed blessing. Those who have gone far enough seemed to perceive more improvement. Despite this, it is necessary to show evidence for improvement in the achieved curriculum. The findings on the achieved curriculum will be described in the next chapter.

Chapter 7: Data analysis – the achieved curriculum

7.1 Overview

This chapter addresses the third research question.

The main question is:

RQ3: Is there evidence of improvement in students' process skills and attitudes on completion of the first year when compared with the old curriculum, and, to what extent is the science self-concept of students influenced by the new curriculum?

The two sub-questions are:

3.1 What process skills, attitudes toward science and science curriculum, and science self-concepts are in evidence among students in the first year of the implemented curriculum?

3.2 How does the new curriculum compare with the old curriculum in terms of students' achievements measured by the parameters mentioned in Sub-question 3.1?

To answer the above questions, analyses were mainly based on data collected from the quasi-experimental study. The data of the student interviews and the teacher interviews were used to illuminate the findings of the study.

7.2 Data from the quasi-experimental study

The findings of the quasi-experimental study were analysed and presented in four parts. The first part reports the demographic data of the sample. The second part analyses students' performance in process skills as reflected by the results of the paper-and-pencil test and the two performance assessment tasks. The third part reports the findings on students' attitudes toward science, attitudes toward science curriculum and their science self-concept. The final part summarizes how the findings can help to answer the research question. A brief description of the statistical methods used for data analysis has been provided in Appendix 7.1.

7.2.1 Demographic data of the student sample participating in the study

Table 7.1 displays the demographic data of the five pairs of classes participating in the study.

School	Matched Class	No. of students		
		Boy	Girl	Total
S1	S1O	23	17	40
	S1N	13	27	40
S2	S2O	21	20	41
	S2O(s)	Removed		
	S2N	22	18	40
S3	S3O1	20	20	40
	S3N1	18	22	40
	S3O2	18	16	34
	S3N2	19	21	40
S4	S4O	21	19	40
	S4O(s)	Removed		
	S4N	22	21	43
S5	S5O	Removed		
Total		197	201	398

(S denotes school, and the number immediately followed is the school number. O denotes the old curriculum and N the new curriculum; when more than one class participated in the study, O or N will be followed by a class number. The "s" in bracket denotes surplus class as a result of the teacher withdrawing from the study.)

Table 7.1: Demographic data of students taking part in the quasi-experimental study

In the first year of the two-year study, there were five schools and eight classes in the sample. The classes were taught by a total of six teachers. However, in the second year, the only teacher in S5 and another teacher of S4 did not teach in Year One. The teacher of S2 was assigned to teach only one Year One class instead of two. This created a surplus of one class for S2 in the old curriculum group. To ensure matching of classes in the two curriculum groups, Class S4O(s) and Class S5O were removed from the study as there were no matched classes taught by the same teachers in the new curriculum group. Class S2O(s) was taught by the same teacher as S2O and S2N. But since S2O was a better match to S2N on the basis of the pre-test scores, S2O(s) was removed instead of S2O (See Table 7.3). In consequence, the new curriculum group was reduced to four schools and five classes. The final sample thus consists of four schools with five matched pairs of classes. There were altogether 398 students, with about 40 in each class. The gender distribution was 197 boys and 201 girls.

7.2.2 Performance on process skills

This section analyses the scores for the three process skill test components, namely the paper-and-pencil test and the two performance assessment tasks, *Solutions* and *Elastic Band* (Appendix 4.12 - 4.17), to give an overall view of students' performance. In order to identify any improvements with the implementation of the new curriculum, the following evidences will be looked for specifically:

- Differences between pre- and post-test scores for each curriculum group;
- Differences between the two curriculum groups in adjusted post-test scores using the pre-tested score as the covariate;
- Differences in gain in score from pre-test through post-test across the two curriculum groups.

The demographic data for the pre-tested subgroup (P) and the non-pre-tested subgroup (X) of all matched classes are displayed in Table 7.2.

School	Matched Class	Sub-group	No. of students (N)		
			Boy	Girl	Total
S1	S1O	S1OP	11	9	20
		S1OX	12	8	20
	S1N	S1NP	6	14	20
		S1NX	7	13	20
S2	S2O	S2OP	10	10	20
		S2OX	11	10	21
	S2N	S2NP	12	9	21
		S2NX	10	9	19
S3	S3O1	S3O1P	10	10	20
		S3O1X	10	10	20
	S3N1	S3N1P	10	11	21
		S3N1X	8	11	19
	S3O2	S3O2P	9	9	18
		S3O2X	9	7	16
	S3N2	S3N2P	10	11	21
		S3N2X	9	10	19
S4	S4O	S4OP	10	10	20
		S4OX	11	9	20
	S4N	S4NP	11	11	22
		S4NX	11	10	21
	Total	Pre-tested	99	104	203
		Non-Pre-tested	98	97	195

(P denotes pre-tested groups and X denotes non-pre-tested groups.)

Table 7.2: Details of groupings within the matched classes

Comparison of pro-test and post-test scores in each curriculum group

Table 7.3 summarizes the pre-test and post-test performance of the pre-tested subgroups of all classes on the three test components.

Matched pre-test group		Mean percentage score							
		Paper-&-pencil test		Solution		Elastic Band		Overall mean	
		Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
S1OP		34	49	17	40	26	44	25	44
S1NP		53	64	33	50	46	66	43	60
S2OP		44	48	31	43	39	56	37	50
*S2OP(s)		43	35	19	26	34	50	31	38
S2NP		35	56	35	45	44	61	39	53
S3O1P		42	52	27	43	38	56	35	51
S3N1P		39	43	40	53	37	78@	38	62
S3O2P		32	40	21	38	28	42	26	40
S3N2P		30	33#	22	38	27	44	25	42
S4OP		50	57	27	37	45	49	40	47
S4NP		50	56	35	42	52	63	45	54
Overall	Old	40	49	25	40	36	50	33	47
	New	41	51	33	46	41	63	38	55

* Class S20P(s) was removed because it is a poorer match with Class S2NP.

@ The highest gain in all tests across all groups;
# The lowest gain in all tests across all groups
Table 7.3: Performance of all classes in the three test components in pre-and post-test

Table 7.3 indicates that all classes in either curriculum groups showed improvement in performance in all tests from pre-test to post-test. The smallest gain, a marginal 3%, was obtained by Class S3N2P in the paper-and-pencil test, while the widest gain was obtained by Class S3N1P in Elastic Band, which is 41%. The difference between the pre- and post-test scores of both the old and new curriculum groups for each of the three tests were shown to be statistically significant using paired-samples t-tests. This implies that both the old and new curriculum seemed to be effective in enhancing students' process skills assessed by each test component. Table 7.4 displayed the results of the paired-samples t-tests.

Test component		**N**	**Mean % score**		**Paired-samples T-test for equality of means**		
			Pre-test	**Post-test**	**t*****	**df**	**p (Sig. (2-tailed))**
Paper and pencil test	**Old**	98	40	49	-4.242	96	.000
	New	99	41	51	-4.045	98	.000
Solution	**Old**	96	25	40	-7.236	92	.000
	New	99	33	46	-5.678	97	.000
Elastic Band	**Old**	97	36	50	-6.033	93	.000
	New	98	41	63	-7.204	95	.000
Overall	**Old**	96	33	47	-9.645	91	.000
	New	91	38	55	-9.220	88	.000

(*** The change in mean % score from pre-test to post-test for all test components is significant at 0.001 level.)

Table 7.4. Results of paired samples t-tests on differences between pre-test & post-test scores

In order to confirm that the improvement was not due to pretest sensitization, the post-test scores of the pre-tested and non pre-tested groups were compared on all three process skills test components using independent samples t-tests (Table 7.5).

Test components	Sub-group	N	Post-test Mean % score	Independent samples t-test for equality of means		
				t	df	Sig.(2-tailed)
Paper and pencil test	Pre-tested	157	48.4	1.381	308	0.168
	Non-pre-tested	153	45.4			
Solutions	Pre-tested	155	42.5	1.919	305	0.056
	Non-pre-tested	152	38.7			
Elastic Band	Pre-tested	156	56.6	-0.730	302	0.466
	Non-pre-tested	148	58.4			
Overall	Pre-tested	148	50.1	1.081	292	0.281
	Non-pre-tested	146	48.3			

Table 7.5: Results of independent samples t-test for equality of means between pre-tested and non-pre-tested subgroups

The results show that all comparisons were not statistically significant at the level of 0.05 (two-tailed), therefore it can be assumed that the pre-test did not exert any significant effect on the post-test scores.

Comparison of post-test scores across curriculum groups

To ensure that the two curriculum groups were comparable to each other, and as a control against influences due to differences in student ability, the two curriculum groups were first checked for homogeneity in terms of student ability, using pretest scores as an indicator. The pre-test scores of the two curriculum groups were compared using independent samples t-test. The results indicate that the two were significantly different from each other, implying that the two curriculum groups did not match in terms of student ability (see Table 7.6). Further examination of the pre-test scores of individual matched pairs of classes indicates a wide difference between the pre-test scores of Class S1OP and S1NP, which is the widest among all class pairs. This shows that Class S1NP was a far more able class than S1OP, presumably as a result of streaming of students by their abilities. In order to confirm that S1 was the chief source of variation, the two curriculum groups were compared again using independent t-test, but with the data of S1 removed. No significant difference in the overall pretest score was found across the two curriculum groups, indicating that the two groups match with each other to a good extent. Hence, it was decided to give up the data of School I in the analysis of process skill scores.

	Independent t-test for Equality of means		
	t	df	Sig. (2-tailed)
With School I	-2.531	193	.012*
Without School I	-1.015	156	.312

(* significant at 0.05 level)

Table 7.6. Results of independent samples t-test for equality of means between pre-test scores of the old and new curricula with and without School I

The post-test score of the two groups were compared using the statistical method of ANCOVA. This was to provide statistical control for the difference in student ability, using the pretest score as a covariate. Before applying ANCOVA, the assumptions of ANCOVA were checked, including linearity in the relationship between the dependent variable (post-test score) and covariate (pre-test score), and homogeneity of slopes i.e. whether the effect of the covariate is the same for the two curriculum groups. Linearity between the post- and pre-test scores were checked by regression analysis. This was done by fitting the dependent variable and covariate into the regression model:

post-test score = a + b(pre-test score)

If p value is significant, then linearity between the two scores can be confirmed. The homogeneity of the effect of the covariate was confirmed by checking if there is a significant interaction between the pre-test score and the curriculum group. If the interaction is not significant, then it could be assumed that the effect of the pre-test score shall be the same across the two curriculum groups.

The results of the tests for linearity and homogeneity of slopes show that both assumptions were not violated for the entire three test components (Appendix 7.1). Hence, the ANCOVA was performed and the results displayed in Table 7.7.

Test component	Curriculum group	N	Post-test % mean score before adjustment	Adjusted % mean score	df1	df2	F	Sig.	Partial Eta Squared
Paper-and-pencil test	Old	98	49.49	49.67	1	193	0.135	0.714	0.001
	New	99	50.63	50.45					
Solutions	Old	96	40.30	41.56	1	188	0.542	0.463	0.004
	New	99	45.77	44.69					
Elastic Band	Old	97	49.76	51.41**	1	187	9.157	0.003	0.058
	New	98	62.59	62.30**					
Overall	Old	96	46.47	47.96*	1	178	5.579	0.020	0.168
	New	91	54.46	53.52*					

***The difference is significant at the level of 0.01 (2-tailed).*

* *The difference is significant at the level of 0.05 (2-tailed).*

Table 7.7: Adjusted mean percentage post-test scores for the old and new curriculum groups using ANCOVA

As shown by the adjusted percentage mean scores, the new curriculum group outperformed the old curriculum group in all the three test components. Yet, the difference was very small for the paper-and-pencil test, and slightly larger for *Solutions*. Only the difference for *Elastic Band* is statistically significant. The overall percentage score of the new curriculum group was also found to be significantly greater than the old curriculum, presumably due to the large difference in *Elastic Band*.

Comparison of gain in score across curriculum groups

Further evidence for differentiating the effects of the two curriculum groups was obtained by computing the gain in scores from pre-test to post-test. If the difference in gain between the two curricula is also large and in favour of the new curriculum, then the findings of the ANCOVA could be substantiated. The results of the computation are displayed in Table 7.8.

Treatment group	Mean gain in percentage score			
	Paper-and-pencil test	*Solutions*	*Elastic Band*	Overall
Old	9.02	15.63	15.03	13.89
New	9.09	12.09	21.32	15.95
Difference in mean gain from old to new curriculum	0.07	-3.54	6.29	2.06

Table 7.8: Mean gain in percentage score for old and new curriculum groups

Although the mean total gain and the gain in *Elastic Band* was still in favour of the new curriculum group, the new curriculum gained less in *Solutions* than the old curriculum group. To check whether the results are consistent among individual matched pairs, the gain in each test component were compared among the four matched classes (Fig. 7.1-7.4).

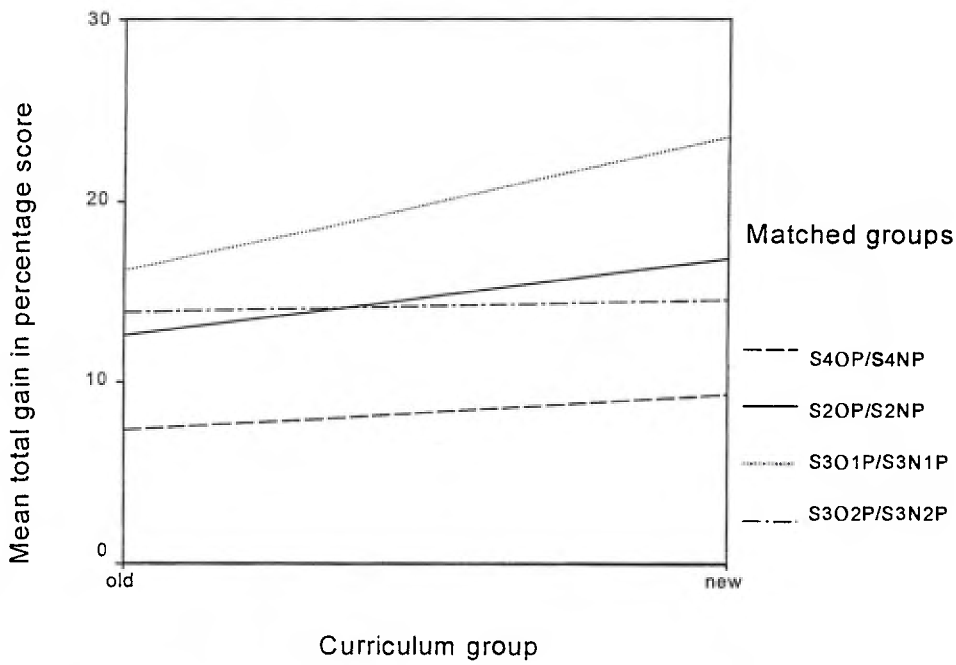

Fig.7.1: Mean total gain in percentage score in different matched groups

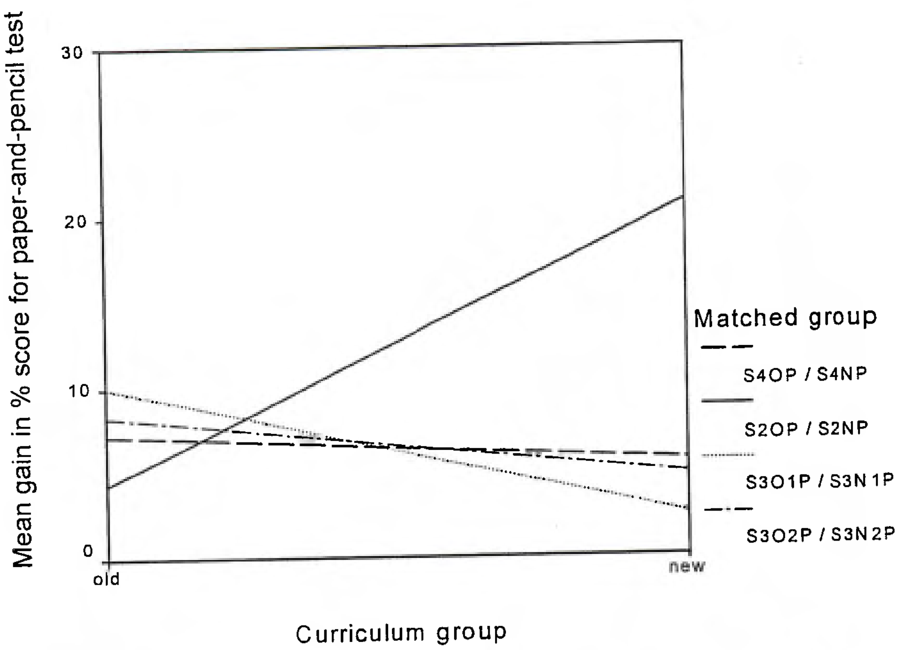

Fig. 7.2: Mean total gain in percentage score in paper-and-pencil test among different matched groups

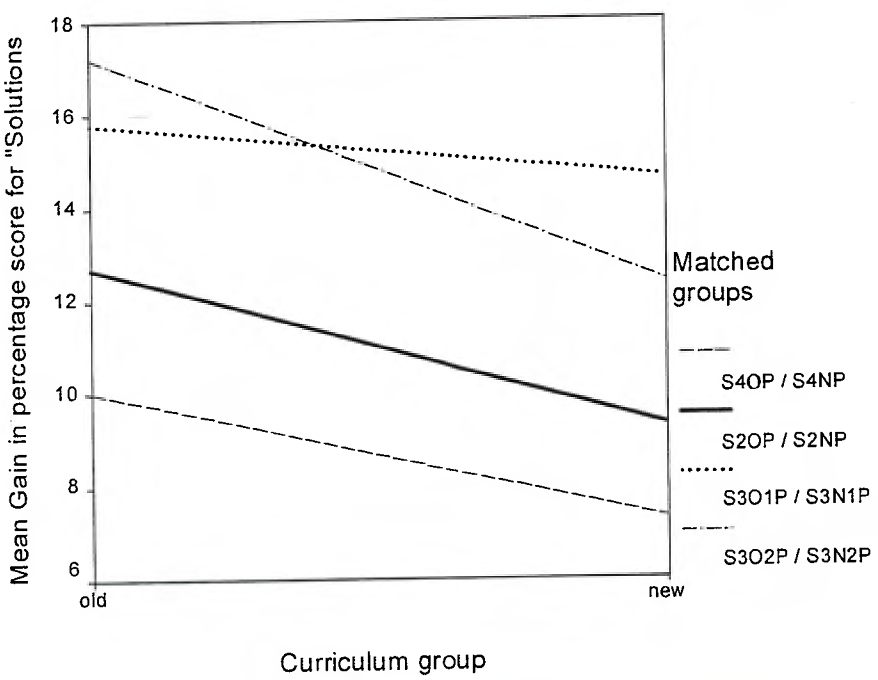

Fig. 7.3: Mean total gain in percentage score in *Solutions* in different matched groups

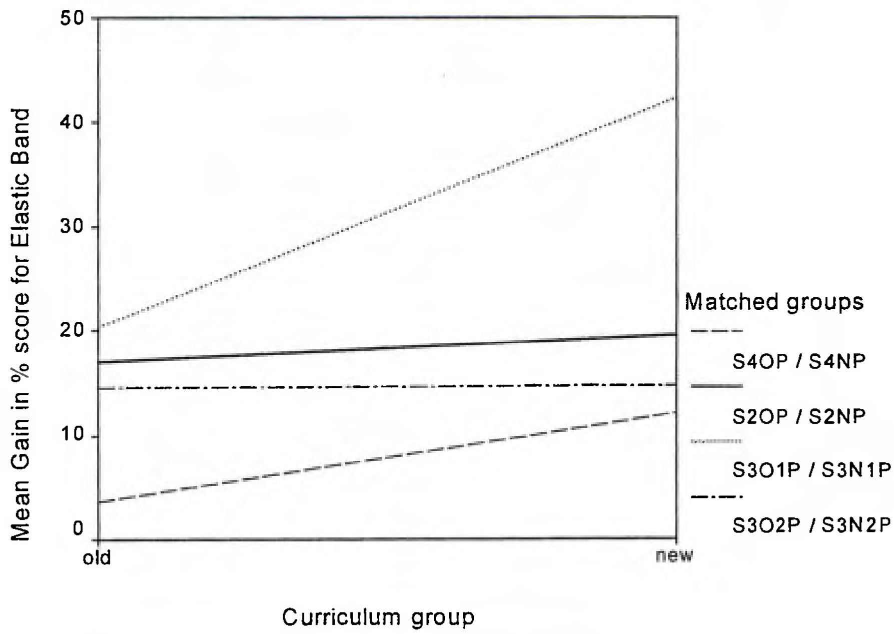

Fig. 7.4: Mean total gain in percentage score in *Elastic Band* in different matched groups

Figure 7.1 shows an upward trend for all matched pairs in the overall gain from the old curriculum to the new curriculum. For the paper-and-pencil test, with the exception of S2O/S2N, which showed an exceptionally large increase in mean gain, all other groups recorded a downward trend under the new curriculum (Fig.7.2). This indicates the marginal advantage of the new curriculum was due solely to this matched pair. This rather anomalous increase in S2 may be due to factors other than the curriculum itself. More uniform changes were generated by *Solutions* (Fig. 7.3). All groups showed a decrease in mean gain of percentage score. This may imply that students in the new curriculum gained less than the other group in terms of the skills required for conducting a more open-ended type of investigation.

For *Elastic Band*, the new curriculum group recorded a greater gain than the old curriculum group in all four matched groups (Fig.7.4). The difference was more obvious in Classes S3O1/S3N1 and S4O/S4N than Classes S2O/S2N and S3O2/S3N2.

Comparatively speaking, *Elastic Band* is less open-ended than *Solutions* and the skills required are of a less complex type compared with those required for by Solutions. So this suggests that the new curriculum might improve performance in less complex process skills.

Gender differences in process skills performance are apparent. As illustrated by Fig. 7.5, boys gained less than girls in the old curriculum group but more in the new curriculum group. This appears to indicate that compared with girls, boys were more able to benefit from the new curriculum than from the old one.

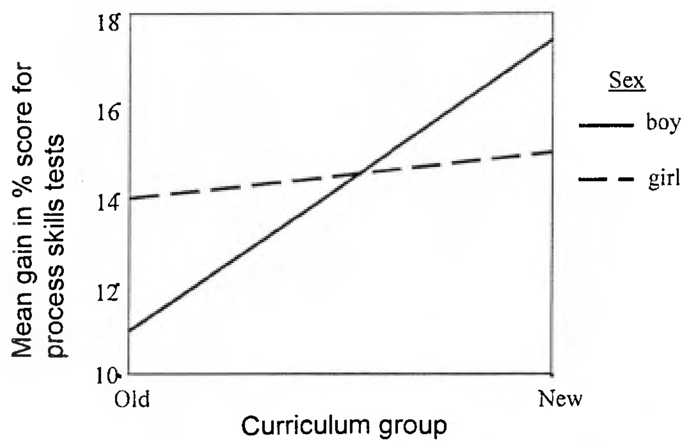

Fig.7.5: Gender difference in gain in mean total percentage score in process skills tests

Performance in the skill components

In order to explore more deeply into the differences in performance of the two curriculum groups, students' performance on individual items of the three process skills test components were analysed. Two criteria were used. The first is to compare the number of non-responses or incorrect responses in which no points were scored. The second is to compare the number of complete responses where full marks were gained. The results of the analyses are displayed in Tables. 7.9, 7.10 and 7.11.

Paper-and-pencil test

Skills to be assessed	No. of points scored in each item	Percentage of students (%)			
		Old		New	
		Pre-test score	Post-test score	Pre-test score	Post-test score
Controlling variables (items 1,4) (Maximum no. of points = 2)	2	12	23	14	23
	1	53	54	51	47
	0	35	23	35	31
Selecting appropriate apparatus (items 2,5) (Maximum no. of points = 2)	2	25	40	23	17
	1	48	42	40	56
	0	27	18	38	28
Predicting data presented in graphical form (item 3) (Maximum no. of points = 1)	1	92	87	88	88
	0	8	13	12	13
Suggesting methods to prove the existence of air (item 6) (Maximum no. of points = 1)	1	47	31	29	58
	0	53	70	72	42
Suggesting materials to use and procedures to follow (item 7) (Maximum no. of points = 2)	2	1	13	0	3
	1	21	31	29	47
	0	78	57	71	51

The items in parentheses represent those items in the test which match to the specified skills .

Table 7.9: Breakdown of test scores by item types for the paper-and-pencil test

In the paper-and-pencil test (Table 7.9), the new curriculum group does not appear to outperform the old curriculum group in controlling variables and selecting appropriate apparatus. Little improvement in predicting data presented in graphical form was observed in both groups, presumably due to the "ceiling" effect since most students had obtained full score in the pretest, so there is little room for any increase. The new curriculum group shows greater improvement in "Suggesting methods to prove the existence of air", but not "Suggesting materials to use and procedures to follow". The latter is thought to be more demanding in terms of the skills required. In fact, both groups performed poorly in this item, and only a very small proportion of students obtained full points. This seems to indicate that the new curriculum was not more effective than the old curriculum in equipping students with skills in planning for more complicated open-end inquiries.

Interestingly, a strongly negative correlation between pretest score and the gain of score was observed. The Pearson Correlation Coefficients for the old and new curriculum groups are -0.602 and –0.571 respectively, both significant at the 0.01 level (2-tailed). This indicates those who scored higher in the pre-test tended to gain less than those with a lower pre-test score. I suggest two reasons for this. The first is that those students who were more capable had already approached the full score in the pre-test, hence the small gain was due to the "ceiling" effect. Second, some items in the test were difficult even for the brightest students, creating an invisible barrier for them to score higher. To check which one is more important, the score distribution of the pre-test and post-test scores for both curriculum groups were examined (Fig.7.6 and 7.7).

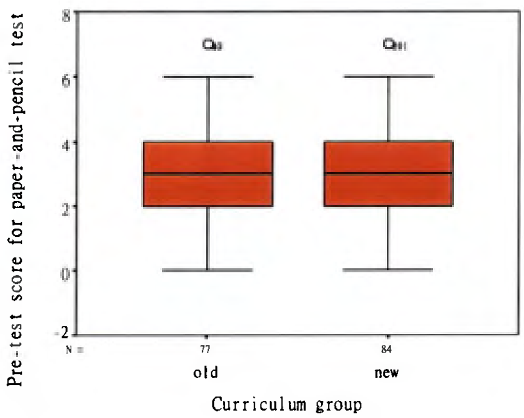

Fig.7.6

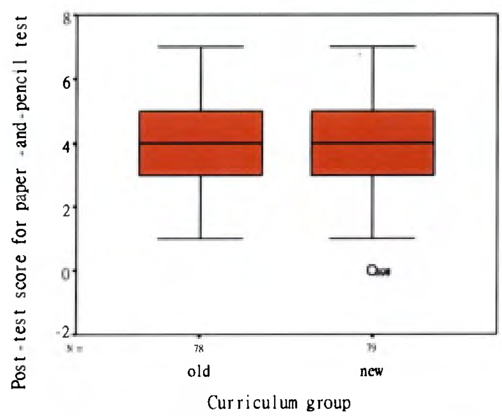

Fig.7.7

Fig.7.6 : Pre-test score distribution of the old and new curriculum groups (paper-and-pencil test)

Fig. 7.7: Post-test score distribution of the old and new curriculum groups (paper-and-pencil test)

The two figures indicate that both hypotheses might account for this anomalous relationship. The top students were approaching the maximum score, which is 8, in the pre-test. Hence, there was likely to be a ceiling effect on the post-test scores. However, the mean score of the post-test was about 4, which is only half of the total score, and the maximum score achieved by the students is 7, still one point short of the full score. This shows that a "barrier" effect also operated at the same time. The main "barrier" was Item 7, which had proved to be the most difficult for the students as shown in Table 7.9.

Solutions

Item type	Response category	No. of points	Percentage of students (%)			
			Old		New	
			Pre-test	Post-test	Pre-test	Post-test
Planning investigation	Complete response	2	0	4	6	6
	Partially complete response	1	8	13	5	19
	Non-response	0	92	83	89	75
Presentation	Complete response	2	0	9	6	25
	Partially complete response	1	48	67	50	54
	Non-response	0	52	24	44	20
Data quality	Complete response	3	13	21	18	37
	Partially correct response	2	26	47	37	37
	Minimally correct response	1	27	21	26	17
	Non-response	0	34	11	19	10
Drawing conclusion	Complete response	2	68	82	67	84
	Partially correct response	1	0	0	2	1
	Non-response	0	33	18	31	15
Explaining conclusion	Complete response	2	0	7	0	3
	Partially correct response	1	25	46	39	43
	Non-response	0	75	47	61	55
Evaluation design	Complete correct response	2	5	8	7	10
	Partially correct response	1	1	7	4	9
	Non-response	0	93	86	89	81

Table 7.10: Breakdown of test scores by item types for "Solutions"

Table 7.10 shows that the new curriculum group improved more in "presentation of data" and "data quality". However, both groups showed more or less the same results in "planning investigation", "drawing conclusion" and "evaluating design". The performance in "planning investigation" and "evaluating design" was particularly low. However, this does not mean that students were incapable of planning their investigation, otherwise they would not be able to record accurate results. While scoring the scripts, I noticed that many students failed to describe their procedure adequately. The most common mistake was to treat the clues to Item (1) of the task (Appendix 4.14) as questions to be answered. Their answers tended to be short, frequently just stating the variables to be measured, without detailing their plans. The following answers reflect their problems:

Q.1 Write your plan here. Your plan should include

- What you will measure ***temperature/time/temperature and time****
- How many measurements you will make ***two times/three times****

*Students' answers.

Hence, these responses imply that many students were not used to writing investigation plan, hence they were not well organized or detailed in describing procedures.

For "evaluating design", less than 20% of students were able to score points. Many of them left the question blank or simply wrote "no change". According to the scoring rubric, students who failed to provide a complete plan in the first item would score zero if they wrote "no change". This may explain why so many students scored poorly in this item. Students' scores in this item may improve if they have drawn a complete plan to the satisfaction of the marker.

"Explaining conclusion", was the only item on which the new curriculum group performed more poorly than the old one. This may be related to the change in curriculum sequence. In the new curriculum the chapter, "The Wonderful Solvent – Water" is taught before "Matter As Particle", rather than the reverse as in the old curriculum. This may explain why students in the new curriculum appeared less capable of applying the particle theory of matter to explain the conclusion than those in the old curriculum.

Like the paper-and-pencil test, the pre-test scores were correlated negatively with the gain of scores in both the experimental and control groups (The respective Pearson Correlation Coefficients are –0.641 and –0.563, both significant at the 0.01 level (2-tailed)). This negative relationship was more significant than seen in the paper-and-pencil test. This implies that better student performance in the pre-test may generate less improvement in the post-test. From the ranges of scores obtained by the two groups in the their respective post-tests (Fig.7.8 and 7.9), although the mean score improved in both curriculum groups, there is still a gap of about 3 points from the full score, which is 13. This implies that the "barrier" effect should have played a more important role than the "ceiling" effect in limiting the brighter students from getting a higher score. The "barriers" were likely to be the items that required students to plan investigation and evaluate their design.

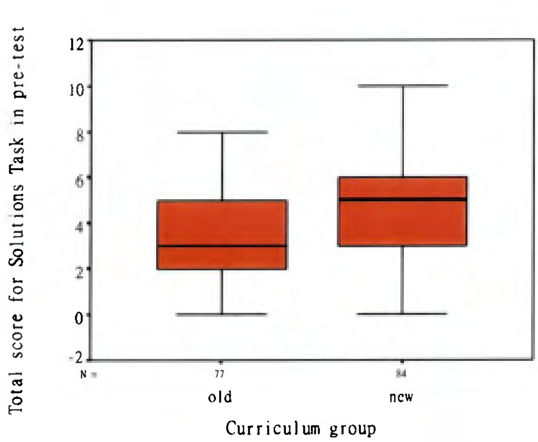

Fig.7.8

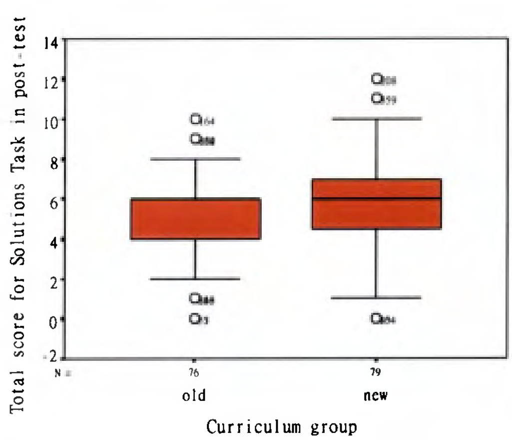

Fig. 7.9

Fig. 7.8: Pre-test score distribution of the old and new curriculum groups (*Solutions*)

Fig. 7.9: Post-test score distribution of the old and new curriculum groups (*Solutions*)

Elastic Band

Item type	Response category	No. of points	Percentage of students (%)			
			Old		New	
			Pre-test score	Post-test score	Pre-test score	Post-test score
Quality of data presentation	Complete response	2	20	38	30	65
	Partially correct response	1	50	44	24	20
	Non-response	0	31	18	46	15
Data quality	Complete response	3	59	71	48	77
	Partially correct response	2	1	8	5	5
	Minimally correct response	1	9	9	6	5
	Non-response	0	31	12	41	13
Graphing results	Complete response	3	14	23	15	37
	Partially correct response	2	13	21	27	30
	Minimally correct response	1	26	35	17	23
	Non-response	0	47	21	42	10
Calculating increase	Correct response	2	28	36	24	41
	Partially correct response	1	0	0	1	0
	Non-response	0	73	64	75	60
Describing trend	Complete response	2	28	40	57	68
	Partially correct response	1	57	49	28	25
	Non-response	0	16	10	16	6
Predicting length	Complete response	1	17	29	21	33
	Non-response	0	83	71	90	67
Explaining prediction	Complete response	2	8	17	11	27
	Partially correct response	1	16	12	11	9
	Non-response	0	77	71	78	65

Table 7.11: Breakdown of test scores by item types for Elastic Band

Table 7.11 shows that students in the new curriculum group gained more than the old curriculum group in all items, with some more prominent than the others. For example, more improvement was shown in the "quality of data presentation", "graphing results" and "describing trend", but less in "calculating increase", "predicting length" and "explaining prediction". This may imply that the new curriculum was more effective in improving less complex skills, like presentation and graphing of data, than in improving more complex skills, like making prediction from experimental data and explaining such prediction.

As in the other two test components, a high and negative correlation exists between the pretest score and the gain in score. The Pearson Correlation Coefficients for the old and new curriculum groups were -0.621 and –0.691 respectively, both being significant at the 0.01 level (2-tailed). Since the top students in the new curriculum groups had achieved the full score, i.e.15 points, even in the pretest (Fig.7.10 and 7.11), the "ceiling" effect should be more important than the "barrier" effect in explaining the negative correlation in this case.

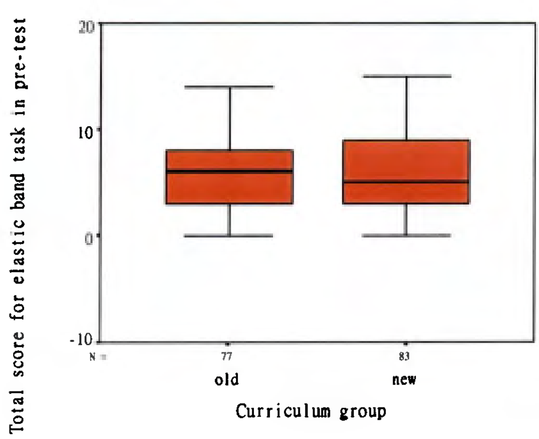

Fig. 7.10

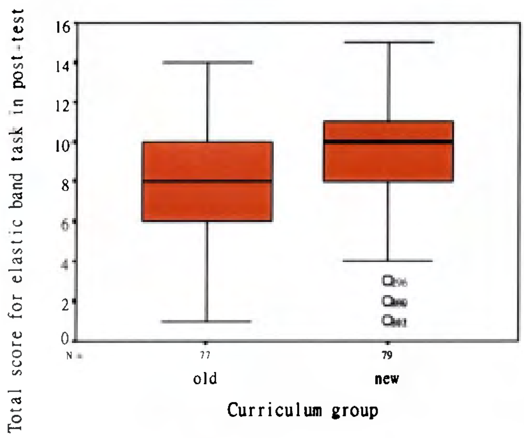

Fig. 7.11

Fig. 7.10: Pre-test score distribution of the old and new curriculum groups (*Elastic Band*)
Fig. 7.11: Post-test score distribution of the old and new curriculum groups (Elastic Band)

7.2.3 Attitudes and science self-concepts

To ensure that the two curriculum groups are comparable in terms of students' initial attitudes and science self-concepts, the pretest scores on the three attitudinal measures of the two groups were compared using independent samples t-test. The results show that there is no significant differences between the two (Table 7.12). Hence, all schools from S1 to S4 were included in the analysis. Table 7.13 displays the students' mean score for the three affective measures.

	t-test for equality of means		
	t	df	*p* (Sig. (2-tailed))
Attitude toward science (pre-test)	-1.459	393	.145
Attitude toward science curriculum (pre-test)	-1.126	393	.261
Science self-concept (pre-test)	-0.365	392	.715

Table 7.12: Results of independent samples t-tests for equality of means between pre-test scores of the old and new curriculum groups on the three affective measures

Matched Classes		**Mean score**					
		Attitude toward science		**Attitude toward science curriculum**		**Science self-concept**	
		Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
S1O		3.96	3.99	4.07	3.97	3.35	3.48
S1N		3.81	3.93	3.91	4.03	3.42	3.38
S2O		3.68	3.53	3.87	3.47	3.19	3.24
S2N		3.69	3.44	3.74	3.39	3.12	3.19
S3O1		3.65	3.60	3.69	3.57	3.31	3.11
S3N1		3.83	3.73	4.25	3.42	3.27	3.40
S3O2		3.48	3.25	3.58	3.10	3.20	3.00
S3N2		3.78	3.27	3.87	3.26	3.10	3.18
S4O		3.77	3.86	3.98	3.67	3.14	3.31
S4N		3.86	3.54	3.90	3.40	3.38	3.19
Overall	**Old**	3.72	3.66	3.85	3.57	3.24	3.23
	New	3.80	3.59	3.94	3.50	3.27	3.26

(The mean score was computed from a 5-point Likert scale. 5 stands for strongly agree and 1 for strongly disagree. Items with negative wordings were adjusted. Therefore a mean score of 3 or above can be considered as positive.)

Table 7.13: Mean score for all matched classes in attitude toward science, attitude toward science curriculum and science self-concept

Similar to process skills tests, the data on the three attitudinal aspects were compared on three parameters, namely the improvement from pre-test through post-test for each curriculum group, the difference in adjusted post-test score between the two groups, and the gain in score from pre-test through post-test for each group.

7.2.4 Attitude toward science

Although the overall mean of all scores was positive throughout the study, all being greater than 3.00, there was a drop in attitude toward science from pre-test to post-test. The deterioration was significant for the new curriculum group but not for the old curriculum group as shown by paired-samples t-test (Table 7.14). This indicates that the new curriculum looks worse than the old curriculum in enhancing students' attitude toward science.

Measures	Curriculum group	Overall Mean		Paired Samples t-test		
		Pre-test	Post-test	t	df	p (Sig. (2-tailed))
Attitude toward science	Old	3.72	3.66	1.350	191	0.178
	New	3.80	3.59***	4.449	195	0.000

*(*** Decrease in overall mean from pre-test through post-test is significant at 0.001 level)*

Table 7.14: Results of paired samples t-test for comparing mean score of attitude toward science between pre-test and post-test

As the assumptions of ANCOVA holds true both for linearity between post-test score and pre-test score, and for homogeneity of effects of the pretest score across the two curriculum groups (Appendix 7.1), the posttest scores of the two curriculum groups were subject to ANCOVA using pretest scores as the covariate. No significant differences were observed between the two curriculum groups (Table 7.15).

Curriculum group	Mean	Adjusted mean	df1	df2	F	Sig.	Partial Eta Squared
Old	3.66	3.68	1	385	3.48	0.06	0.01
New	3.59	3.57					

Table 7.15: Adjusted mean percentage post-test scores for the old and new curriculum groups using ANCOVA

A comparison of the gain in attitude toward science from pre-test through post-test across the two curriculum groups shows that the gain was more negative for the new curriculum groups than for the old group (Table 7.16). This shows that the attitude toward science deteriorated to a greater extent in the new curriculum than the old curriculum, and the difference is statistically significant ($p<0.05$).

Curriculum group	N	Mean gain in attitude toward science	T-test for equality of means		
			t	df	p (Sig. (2-tailed))
Old	192	-0.06*	2.31	386	0.021
New	196	-0.21*			

(Difference in mean gain in attitude toward science between the old and new curriculum groups is significant at 0.05 level)*

Table 7.16: Difference in mean gain in attitude toward science between the old and new curriculum groups

This finding corroborates the evidence obtained from the pair-sampled t-test that the new curriculum fared more poorly than the old curriculum in developing students' attitude toward science. In fact this downward trend from the old to the new curriculum was consistently shown in all matched pairs except for School 1 as displayed in Fig.7.12. Although both boys and girls exhibited this downward trend (Fig.7.13), this was particularly obvious in girls who showed a significantly more negative gain in the new curriculum group (Mean = -0.29) than in the old group (Mean = -0.06), t(196) = 2.75. p<0.01. Yet, comparison of adjusted post-test scores for girls across the two curriculum groups shows no significant difference.

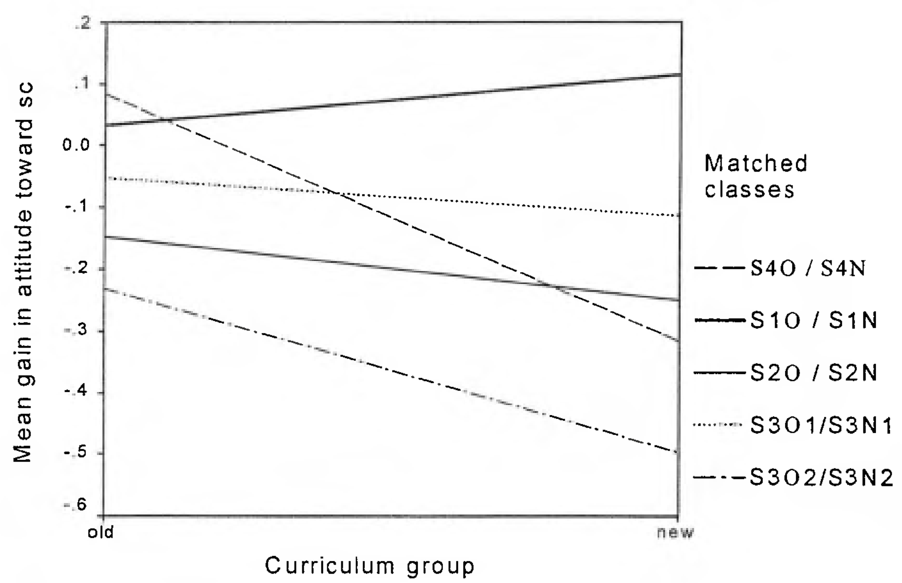

Fig.7.12: Mean gain in attitude toward science by different matched classes

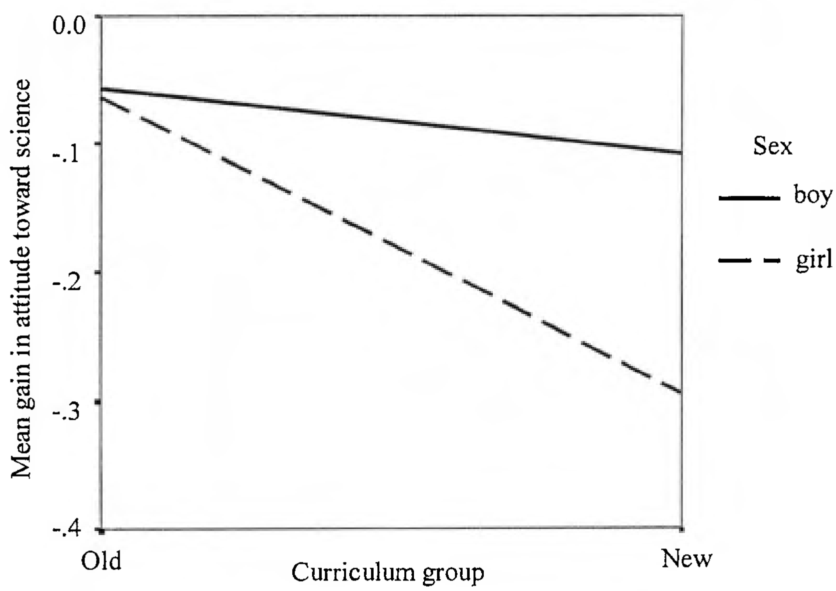

Fig 7.13: Gender difference in gain in attitude towards science

7.2.5 Attitude toward science curriculum

There was a deterioration in students' attitude toward science curriculum from pre-test to post-test for both curriculum groups, and the degree was even more pronounced than for attitude toward science. The results of paired samples T-test displayed in Table 7.17 confirm that the decrease in attitude toward science curriculum is significant for both curriculum groups (p<0.001).

Measures	Curriculum group	Overall mean		Paired Samples T-test		
		Pre-test	Post-test	t	df	p (Sig. (2-tailed))
Attitude toward science curriculum	Old	3.85	3.57***	5.423	191	0.000
	New	3.94	3.50***	5.371	195	0.000

*(*** Decrease in overall mean from pre-test through post-test is significant at 0.001 level.)*

Table 7.17: Results of paired samples T-test for equality of means of attitude toward science curriculum between pre-test and post-test

Since the effect of pre-test score in different curriculum groups was not homogeneous (Appendix 7.1), the mean post-test scores of the two curriculum groups could not be compared by ANCOVA using pre-test score as the covariate. Judging from the overall post-test mean for all corresponding classes, the post-test results of the old curriculum group (M=3.57) was similar to the new curriculum group (M=3.50) and there is no statistically significant difference between the two, $t(389)=0.848$, $p>0.05$. Thus, prima facie evidence seems to suggest that students did not find the new curriculum more attractive than the old one. In contrast to attitude toward science, no evidence of gender difference in attitude toward science curriculum was found in pre-test and post-test means for both groups.

Figure 7.14 shows that the deterioration in attitude toward science curriculum was consistent across different matched pairs except S1, which recorded a small increase in gain in the new curriculum. This finding concurs with the previous one, showing that attitudes toward science and science curriculum were closely related. From the findings of the teacher interviews reported in Chapter 6, the consistent improvement shown by S1 under the new curriculum with regard to the two attitudes was probably related to the teacher. The teacher in S1 was shown to be more familiar with the new curriculum and more committed to implementing the reform. Hence, it was more likely for the students to develop positive attitudes toward science and the new curriculum.

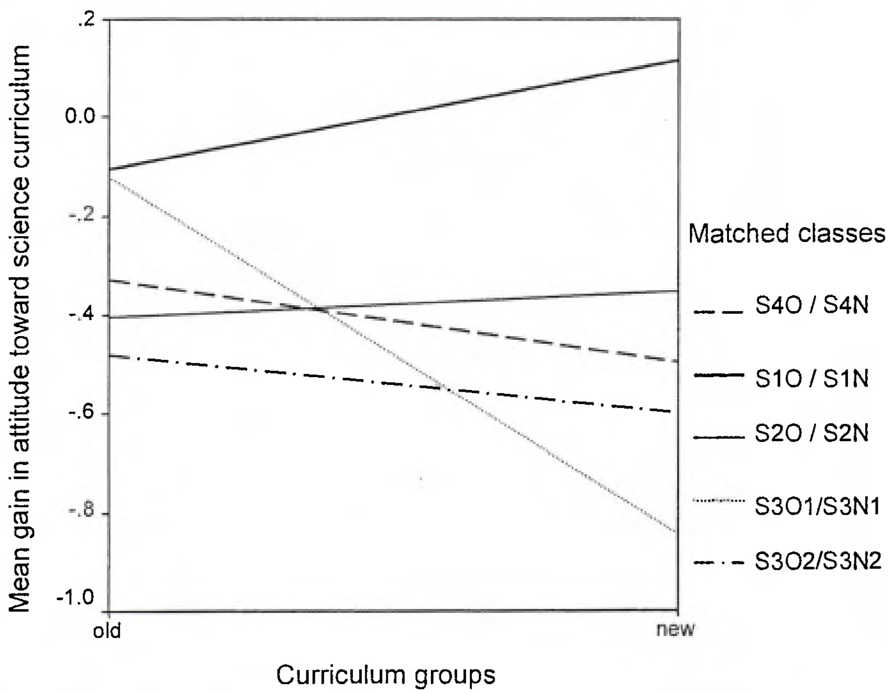

Fig. 7.14: Mean gain in attitude toward science curriculum by different matched classes

7.2.6 Science self-concept

Table 7.13 shows that mean science self-concept appeared much more stable with time and across curriculum groups than attitudes toward science and science curriculum. There was only very little difference between the two curriculum groups from pre-test through post-test. The very slight decrease in the mean science self-concept through the year under both curricula implies that the curriculum had only a minimal effect on this attribute. Despite this, Fig. 7.15 indicates that there were variations among the matched pairs, implying that the trends were different from school to school, to the extent of being contradictory with one another. For instance, S1 and S4 recorded a positive gain under the old curriculum but a neutral or even negative gain under the new curriculum. This situation was almost reverse for the two matched classes of S3. It appears that other factors might interact with the curriculum to produce such a variation. The teacher may have a role to play in facilitating changes in students' science self-concept. This is suggested by the fact that the two classes, S3N1 and S3N2 that showed substantial gain were taught by the same teacher. Nevertheless, such inference has to be considered cautiously, and more evidence is needed to draw a firm conclusion.

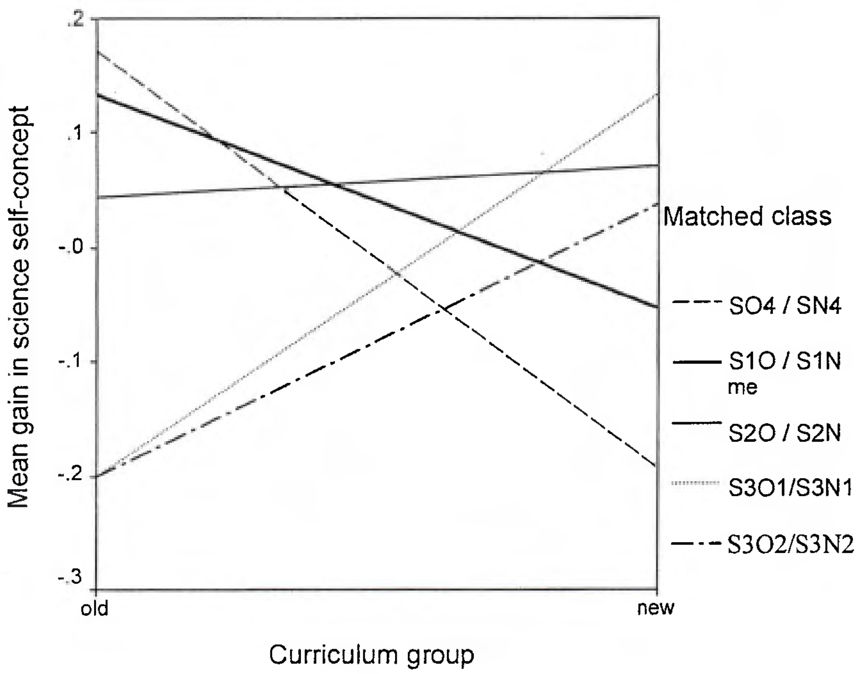

Fig. 7.15: Mean gain in Science Self-concept by different matched classes

It is also interesting to note a gender difference in gain in science self-concept from pre-test through post-test between the two curriculum groups. As shown in Fig. 7.16, boys and girls exhibited opposite trends. There was a positive gain in science self-concept for boys but a negative gain for girls in the change of curriculum. This gender difference was found to be statistically significant (Table 7.18). The post-test science self-concept of the two sexes in both curriculum groups were also compared using ANCOVA with the pre-test science self-concept as the covariate. Details of the tests for linearity of dependent variables and covariate and for homogeneity of slopes are provided in Appendix 7.1. The adjusted post-test means of the two sexes in the new curriculum group also shows a statistically significant difference in favour of boys. No such statistical significant gender difference was observed in the old curriculum group (Table 7.19).

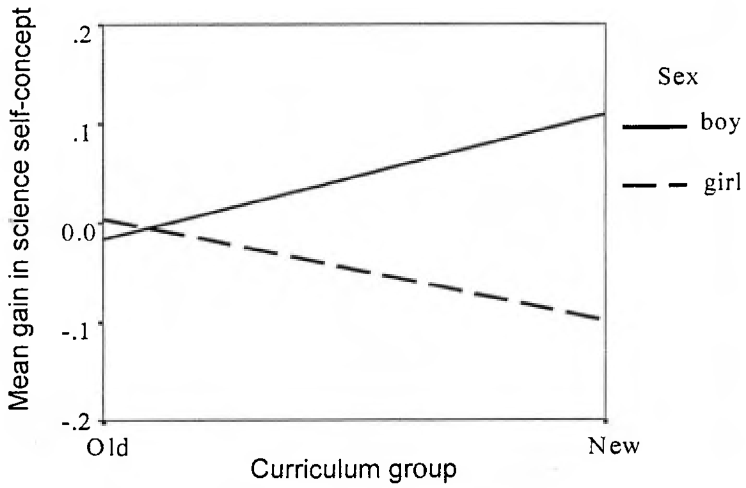

Fig. 7.16: Gender difference in gain in science self-concept

Gender in the new curriculum group	N	Mean gain	Independent T-test for Equality of Means		
			t	df	p (Sig. (2-tailed))
Boy	89	0.11*	2.15	193	0.03
Girl	106	-0.10*			

(Difference between mean gain is significant at 0.05 level)*

Table 7.18: Results of independent samples t-test for equality of mean gain in science self-concept by boys and girls in the new curriculum group

Curriculum group	Sex	Mean of posttest score	Results of ANCOVA				
			Adjusted mean	df	F	Sig.	Eta Squared
Old	M	3.29	3.26	1	0.614	0.434	0.003
	F	3.17	3.20				
New	M	3.41	3.39**	1	7.875	0.006	0.039
	F	3.20	3.15**				

*(*Difference between adjusted posttest scores of males and females is significant at the level of 0.01.)*

Table 7.19: Gender difference in adjusted mean post-test scores in science self-concept for both curriculum groups

7.2.7 Discussion

Process skills

Comparison of adjusted post-test means after controlling for pre-test differences indicates that the new curriculum recorded a statistically significant higher score than the old curriculum. Detailed analysis of the individual test components revealed that this was mainly contributed by the difference in performance of the two groups in *Elastic Band.* In contrast, no statistically significant improvement was shown in the paper-and-pencil test and *Solutions.* Apart from the adjusted posttest score, some improvement was observed in the gain in score from pre-test through post-test, There was a greater gain in the new curriculum group on *Elastic Band* than in the old curriculum group, but the outcome was reversed for *Solutions*. Most of the matched classes exhibited similar trend as the overall one, indicating that the findings were consistent and reliable.

Although the data seem to support the hypotheses that the new curriculum could lead to improvement in students' process skills, but as the samples were not randomly selected, caution has to be taken in generalizing the statistical findings. The strongest evidence was derived from analysis using ANCOVA. However, the covariates might not be limited only to the pre-test score. Also, for comparison of gain in score between the two curriculum groups, the computation of score gain from pretest and posttest scores may enlarge the error in these two sets of data, resulting in a larger statistical distortion of the real picture. Nevertheless, reliability will increase when both the adjusted post-test scores and the gain in scores indicate the same trend, and when the same trends are consistently shown across different matched pairs of classes.

The analysis of students' performance in individual items of the three test components yielded more in-depth information about students' performance. Students performed rather differently in different items, dependent on at least four factors. The first factor is the complexity of the process skills involved. Students in the new curriculum group in general showed a greater improvement in items that assess less complex skills, e.g. data presentation and describing a trend (*Elastic Band*) (Table 7.11), than those assessing more complex skills, e.g. suggesting procedures (paper-and-pencil test) (Table 7.9) and evaluating design (*Solutions*)(Table 7.10).

The second factor is the context in which the skills were assessed. For instance, students performed very well in Item 3 of the paper-and-pencil test, in which students were required to predict data from a hypothetical, perfect linear graph (Table 7.9). However, in a separate item of *Elastic Band* where students were required to predict length from a real set of data in a table or graph derived from their own measurements, students did rather poorly. This indicates that students could handle problems better in a theoretical and simple context of investigation than in a real and messy one.

The third factor is related to the degree of openness of the items. Students performed more poorly in more open situations. For instance, in the paper-and-pencil test, students did better in suggesting methods to prove the existence of air (Item 6) than in suggesting materials to use and procedures to follow in the investigation of heart rate (Item 7). Another example is that students found it more difficult to record data by making their own table (*Solutions*) than by filling out a partially constructed table (*Elastic Band*).

The fourth factor relates to the poor ability of students to write out their investigation plan in an organized manner. This seems to indicate that students lacked the experience or training in describing investigation plans with all the necessary details including procedures and how variables were to be controlled. This is consistent with the study by Toh, Boo and Yeo (1997), which found that 13-year old Singaporean students could do more than they can tell. There were two reasons as suggested by the findings. The first reason is that students might lack the experiences of designing an open investigation like "Solutions" in their class. Secondly, they might not be used to provide a full record of the activity. Such weaknesses had affected the performance of both curriculum groups. In addition, the new curriculum appeared to favour boys rather than girls suggesting that the new curriculum is more suitable for boys.

Correlational analyses show that for both curriculum groups, the more able students improved less than the less able ones across all process skills tests. The reason was that even the more able students failed to master some complex skills such as planning investigation and evaluating designs. This implies strongly that the more able students were not sufficiently challenged in developing more complex skills even when the new curriculum was in place.

Attitudes and science self-concept

While students still possessed positive attitudes toward science and science curriculum at the beginning and toward the end of the course, they showed a downward trend in general. This may imply that toward the end of the year, both curricula had failed to sustain the same level of interest generated at the start. For attitude toward science, the deterioration was only significant for the new curriculum. This seems to indicate that the new curriculum fared more poorly than the old curriculum in terms of attitudinal development. The downward trends appeared in most of the matched pairs, indicating that the overall results were reliable.

The change in students' science self-concept appeared to be inconsistent across different matched pairs despite the fact that the overall mean remained stable in both curriculum groups. This leads to the inference that this attribute was likely to be influenced by variables other than the curriculum itself. Consistent with the findings on process skills assessment, the results also show a notable gender difference in the change in attitude and science self- concept in favour of boys. Girls deteriorated to a greater extent than boys in their attitude toward science in the new curriculum than in the old curriculum. For science self-concepts, girls showed a similar deterioration in the change of the curriculum, while boys showed some improvement.

7.3 Data from student interviews

7.3.1 The sample

Six students from each class participating the quasi-experimental study were randomly selected for interviews to collect their views about the test and the curriculum. Altogether, the sample consists of sixty students, with thirty students in each of the two curriculum groups. Of these students, 32 were males and 28 females.

7.3.2 The findings

The responses across classes and curriculum groups were strikingly similar. I found it useful to categorize students' responses into themes that naturally emerged from the interview data. These themes were displayed in Table 7.20. The raw data categorized under each theme were presented, as it is to capture the authentic views and feelings of the students. In order to ensure validity and reliability, only those comments corroborated by two or more students within an interview group are shown. The classes to which the students belonged were also reported to indicate whether the trends were common across classes.

Theme/Pattern	Students' responses			
	Old curriculum group	Class	New curriculum group	Class
1. Students were unfamiliar with a more open-ended type of investigations	"We learnt a lot in our lessons, but it seems that we have nothing like this one (Solutions)."	S3O1	"Our teacher will explain every procedure before we proceed with an experiment. There is no need to think over it like what we did in those assessment tasks."	S1N, S2N
	"We need to think this time. Previously, the teacher told us what to do."	S1O, S4O	"There is very little similarity with what we are doing in class. We have worksheets to fill out. We don't need to write procedures or plan. We haven't tried to design experiments before."	S4N
	"The textbook provides us with all the procedures of experiments."	S3O1	"We haven't done this kind of open investigation (Solutions) in our class, not even once."	S2N
			"We were mostly guided by our teacher."	S3N1
2. Students felt that the assessment tasks are more difficult or challenging than the activities they have in their classes	"The tasks are more difficult than the activities we did in our class. Our teacher would teach us step by step."	S1O, S2O	"They are fun. We didn't have that kind of activities in our lessons (Solutions and Elastic Band)."	S1N, S3N1, S4N1
	"It's more interesting and more fun than our normal class activities. This time we were free to decide what to do."	S4O	"These (assessment) tasks really provoke our thoughts."	S2N
	"It is getting boring when you know the answers from the textbook already. We even got the diagrams of the results in our textbook!"	S3O2, S2O, S4O	"Doing these tasks made me feel that I am too dependent on my teacher. That may be the reason why we didn't know how to think through the task."	S1N
			"I think these activities are more challenging than what we did in class. I got the feeling that the more we think, the more we understand."	S1N
3. Students felt uncertain while proceeding with the investigation, and there was a lack of confidence when there is divergence	"This is difficult because this time I have to decide on myself."	S1O	"We like these tasks but we are unsure of the accuracy of our procedures or our results, whether we were in the right direction or not."	S1N, S3N1
	"We are used to follow the procedure in the textbook. But this time, we varied a lot." E.g. "Some of us stirred but some did not."	S3O2, S2O	"I was afraid of doing it incorrectly."	S1N

	"There were a lot of differences between my data and the others'. We usually got very similar ones." " I'd rather follow the textbook because there are procedures to follow. We would know how to use the equipment. It's easier to understand." "I like being guided by our teacher as we have now because it is easier and clearer." Although your tasks are more fun, but I don't prefer to do that all the time because there are no standard results. What we got were so different from the others."	S3O1 S3O1 S1O S4O	"I prefer to stick to our normal way of doing things because I feel more certain of what is correct and what's not."	S1N
4. Students have little idea of the need to draw up a written plan and the sort of plan required (for Solutions) nor do they know why and how to evaluate their plan	" I didn't realize that I have to write out a plan." " I have thought about it but I haven't written it out." "I found it difficult to express myself."	S3O1, S3O2 S3O1 S4O	"I didn't know what was required." "I mistook the question (Question 1 in Solutions) as guidelines, therefore I didn't answer that part." "I didn't realize that I have to write out the procedure." "I don't think I need to change my plan." "I don't have a clue as to what was needed to change."	S1N, S3N2 S3N1 S4N S2N S1N
5. Insufficient understanding of techniques in presentation . Ready-made tables were provided. Drawing of graphs was rare.	"I don't know what kind of table was required. We weren't told about this in the task (Solutions)." "I wasn't sure what to include in the table, …hot water, cold water, or rate of dissolving." " I don't know where to draw the lines in the table." " We don't draw graphs in science classes." "We do that	S1O S3O2 S1O S1O,	"We need to write answers to questions and our teacher will discuss with us in class the correct answers." "We only need to write a little bit and in brief only. There is no need to write out in detailed manner." "We do not need to make tables ourselves. They were provided in the textbook."	S1N S4N, S3N1 S1N

	only in Math. Lessons." "I don't understand how I should draw the table, so I just wrote the results in words." We seldom draw tables in our class	S3O1 S2O S4O		
6. Students desired to have more experiments in their science classes	I would like to have more experiments to make the class more interesting. "I wish our teacher demonstrate less, and let us do it first." "We did very few experiments."	S1O, S3O1, S4O S3O1 S2O	"I would like to have more activities." "We prefer to do more experiments. The lessons are boring." "I would like to have more experiments. It is easier to understand the abstract things by doing it." "There is little interest in science. All we have is teacher talking for most of the time."	S3N1, S3N2 S2N S4N S4N

Table 7.20: The six themes emerging from student interview data

The following paragraphs provide further information concerning these six themes as synthesized from the interview findings.

Theme One: Unfamiliarity with a more open-ended type of investigation

Students of both curriculum groups found that the assessment tasks, in particular, *Solutions*, were unfamiliar to them. This is evident in students' responses like 'We have nothing like this', 'We haven't tried to design experiments before', 'We are mostly guided by our teachers', etc. In the eyes of the students such open-ended activities like *Solutions* was very different from the kind of work they usually performed in class. It seems that their normal process of going about an experiment or investigation activity was for the teacher to explain the procedure to students, or to guide them in a stepwise manner to obtain the final result. The following extract of the interview transcript for Class S1N is just an example.

Interviewer: How are the assessment tasks different from what you did in your class?
Student A: We usually conduct activities in groups but this time we did it individually.
Student B: Normally our teacher would give instructions, but there are no instructions this time.
Interviewer: How does your teacher give instructions?
Students A: Our teacher would tell us every step. You don't need to think it out by yourself.
Interviewer: Have you done the experiments to find out the factors that influence the rate of dissolving in class?
Student B: Yes.
Interviewer: How did you do that?
Student B: Our teacher told us the procedure.

Science practical work in many of these classes seemed to be dominated by a close-ended approach and by uniformity in fine details of experimental procedure. This approach in conducting experimental activities seems to have little changes in the new curriculum. The interviewees seemed to be quite aware of the distinction between the two types of approaches represented by their class practical work and the performance assessment tasks, and the implications of the two for their own learning. This is reflected by the following comments.

> *"I'd like to be provided with experimental procedures but I know it is better for us to sort them out by ourselves. You know, sometimes our teacher would even demonstrate the experiment to the class before letting us do it."* (A student of Class S3O1)

> "Doing these (performance assessment) tasks makes me aware that we were too dependent on our teacher. That's why we didn't know how to investigate on our own." (Two students of Class S1N)

The above reflections by students provide further evidence as to the gap between the conceived curriculum and what was actually occurring in their classroom or laboratory.

Theme Two: Perceiving the assessment tasks as more interesting and challenging

Students of both curriculum groups had a general feeling that the performance assessment tasks were more challenging and more fun in contrast with what they did in science class. This is evident in the use of expressions like, "more interesting", "more fun" and "more difficult" by students in the old curriculum group; and "provoke thoughts", "more challenging", and "fun" by those in the new curriculum group. One student in the new curriculum group put it like this:

> *"These tasks at first looked difficult, but I could feel a sense of achievement when I managed to obtain good results."* (A student of Class S3N1)

These expressions or remarks indicate that such kind of rewarding experiences generated from participation in investigative activities were not typical experiences of the students, which reinforces the previous inference that an open-ended type of investigation led by students themselves was not commonplace in those classes.

Theme Three: Feelings of uncertainty and lacking in confidence in students

Although students generally found the assessment tasks challenging, they at the same time felt uncertain in conducting the investigation. From the findings, it is commonplace that students felt unconfident as they proceeded with the tasks. Again, this could be explained by the fact that students lacked experience in conducting open investigations. Students seemed to be struck by the idea that experimental procedures could vary, depending on the experimenter. Some of them had become rather uncomfortable with the data they got which appeared to be so diverse. This experience seemed alien to them. The following comments made by the following students exemplify this phenomenon.

> *"...but this time we varied a lot. Some stirred but others did not."* (A student of Class S4N on Solutions)
> *"...Doing experiments in this way.... might lead to very different results....., could be 1 cm longer or 1 cm less. There was always a worry that I was wrong.."* (A student of Class S2O on Elastic Band)

This worry of failing to obtain "standard" results appears to stem from the conception that there is a body of unequivocal knowledge to be learnt from science and doing experiments is a means of acquiring it. Hence, something must have gone wrong if the experimental results deviated from that set of knowledge. This conception or misconception seemed to exist in both curriculum groups, and might be attributed to the dominance of guided discovery despite the curriculum change. This lack of confidence had caused some students to seek refuge in the guided discovery approach so as to regain a sense of security.

> *"I prefer the way we are working now, because I could be more certain of what is right. I wasn't sure whether I was on the right track in these tasks."* (A student of Class S1N)

Theme Four: Lack of idea in writing a plan

Apart from the above, students seemed to be unaware of the need to present their experimental design, or, did not have sufficient ideas as to how to go about this. Since students were reminded to do so during the test, they should be aware of the need to write out the plan. From the responses provided by the students, it is more likely that students did not understand the exact requirement of such a plan. Some students said that they didn't realize they had to describe the procedure. Some mistook the question as guidelines, hence they just made a simple response to them. Some seemed to be inhibited by the difficulty in expressing themselves. A possible explanation is that students lacked practice in putting their ideas into a relatively detailed plan since they were used to follow the guidelines on the textbook or the instructions of their teacher. The same problem was observed when students were asked to evaluate their design. The interviewees either thought that changes were unnecessary despite the fact that their plans were incomplete, or they did not have a clue as to what changes were necessary. Yet, there might be an even more fundamental cause to students' poor performance, as reflected in the following extract.

> *"I found some of the questions very abstract and difficult to understand. For instance, since the whole thing (experiment) was already over, what was the point of asking us to suggest changes?"* (A student of Class S2N)

This student obviously failed to appreciate the spirit of scientific investigation as a continuous, yet meticulous process for seeking a more reliable and genuine conclusion. It also reflects a lack of exposure of students to a more open-ended type of investigation, since the understanding of this spirit could not have been developed in students without sufficient hands-on and minds-on experiences of using the scientific approach. Another student of the same class confirmed this lack of exposure.

"We haven't done this kind of open investigation (Solutions) in our class before, not even once." (Students of Class S2N)

Theme Five: Insufficient understanding of the techniques for presenting results

Another common theme across the two curriculum groups is students' unfamiliarity with the drawing of tables for presenting experimental results. It seems that some students had a poor understanding of the meaning of "table".

"I misunderstood the word, table. I thought I needed to draw a bar chart." (A student of Class S3N1)
"I didn't understand which kind of table was required. There are different kinds of tables. Some are graphs, some are made of words...." (A student of Class S2O)
"I didn't understand what was required. I thought it's better to write out the results." (A student of Class S3N2)

There were also cases in which students knew the meaning of tables but were not sure how to make one that suits this purpose. For instance, there were uncertainties as to what variables should be included.

"I know a table consist of boxes, but I did not know how to make one for this question." (A student of Class S2O)
"I wasn't sure what to include in the table, ...hot water, cold water, or the rate of dissolving." (Class S3O2)

The reason for students' difficulties in drawing tables was obviously that they seldom needed to make one out of their own because tables were ready made for them in their textbook. Nevertheless, there were students who were able to overcome the difficulty.

"It looked difficult at the first glance. But if we are more careful, we should be able to make one." (A student of Class S2N)

Students responded rather frequently that they needed to write in greater details in the assessment tasks than they used to do. As reported by the interviewees, their usual practice was to write short answers to questions, followed by teacher-led discussion, and the teacher would provide the correct answers afterwards. The following dialogue between two students of reveals their feelings about the writing work required of them in *Solutions*, and how they made sense of them.

Student A: "I think they are quite difficult, in particular the questions on P.2 and 3 (of Solutions)... have to describe and explain.... I've got the feeling like writing an essay." (Class S3N2)

Student B: " I think this is good. Isn't it true that science is for the training of our mind?" (Class S3N2)

Theme Six: Desire to do more experiments in science classes

There was a rather unanimous feeling among students of all classes that they would like to have more practical activities in science classes, which was true for both curriculum groups. The reasons given by students were that experimental activities helped them understand concepts that were more abstract, and made the learning process more interesting. This desire seems to be most strongly expressed by Class S2N and Class S4N from the response made by students of these two groups. There was clearly a mismatch between students' expectation of what science classes ought to be and the reality they experienced in their classes. The following is an excerpt from the interview with students of Class S4N:

Interviewer: "What changes would you like to see to the present science curriculum, anything from content to teaching?"
Student A: "I would like to have more experiments. I would like to make my own record. There were just too few experiments for us to do. We could do experiments only in laboratory class. But, we have class in the laboratory for only one double period (in a 6-day cycle). Most experiments are done by our teacher."
Student B: "I too prefer to have more experimental activities."
Interviewer: "What other things would you like to change or to learn?"

Student B: "I have no interest in science. There isn't much interest. It's talking all the time. It's boring. There's should be more doing.... The book is dead, but we are living beings."
Student C: "We should do more experiments. That would make abstract things easier to understand."

7.3.3 Discussion

Judging from the interview data provided by the two curriculum groups, there seemed to have little change in the way experiments or investigations were conducted in their classes with implementation of the new curriculum. There were still too few opportunities for students in the new curriculum to perform a more open-ended type of investigation comparable to the TIMSS performance assessment tasks. In contrast with the TIMSS tasks, the laboratory activities experienced by students were perceived to be less challenging, teacher-directed, and less thought provoking. There was also little demand for students to report their plan and findings in a detailed and authentic manner. The amount of writing was dictated by the format provided by the publishers' worksheets, which were rich in guidelines. In consequence, there was a general lack of confidence among students in tackling self-directed investigations, and in presenting authentic data. This might explain why students made little improvement in describing their plans and presenting data in table form in the posttests.

Although most students would like to perform more practical work in science classes, there was ambivalence in students' attitudes toward more open investigations. Students thought that these open investigations as characterized by the TIMSS tasks were challenging, but they would feel more secure by sticking to their usual practice in doing practical work. Their emphasis on "accurate procedure" and "obtaining standard results" further reflects that their concepts of science practical work were close-ended and definitive, which may explain why students were weak in evaluating investigation design and procedures. To students, science knowledge seems to be authoritative which is to be acquired rather than developed by themselves in the inquiry process. All these findings imply that students in the new curriculum had yet to develop appropriate skills, sufficient confidence, and a habit of using the investigative approach to tackle scientific problems.

7.4 Teachers' views about the findings of the study

7.4.1 Process skills

During the second interview with the four teachers, they were invited to express their feelings or to comment on the test results of their classes. Ching (S1) said the improvement shown by her students in the new curriculum were less than what she expected. She thought the new cohort should have a higher gain because they had significantly better pre-test results than the one under the old curriculum. She suggested this might be due to insufficient training, and the assessment tasks being too demanding and not sensitive enough to identify modest improvements. Her responses were reflected in the following extract:

> *"There is always a difficulty to improve the performance of the more able students. I think training might not be sufficient, particularly on the writing part. Also, students were used to working in groups, but this time, had to work individually. Moreover, I think it really needs time for students to show improvement in investigation, so we couldn't expect a great improvement in such tasks that aimed at such an intensive assessment of process skills. In a way, these tasks were too demanding for them because of the short duration they were given to provide an answer. I think they just needed more time to think them over, say, how they could improve their design of the experiments to obtain more accurate results.... I would say that the assessment tasks you used might not be able to tell the fine improvement made by students.*"

Yan (S2) was rather surprised by the fact that students in the new curriculum gained a greater improvement in *Elastic Band* than *Solutions*. This was because her students had conducted similar kind of experiments on dissolving but not on *Elastic Band*. However, she conceded that they were not accustomed to going through the investigation in such details. She further explained her views about the difference in student performance in these two tasks.

> *Normally, I just let students discuss the design orally, so there was no need for them to write it out. There was also no need for them to explain their results in detail. There was only little mentioning about evaluation of experimental design. We mainly followed the textbook. For Elastic Band, students should find it easier because they have learnt some statistics in their mathematics class.*

Fong (S3) echoed the views of Yan. She also suggested that the lack of improvement for *Solutions*, which she was most concerned about, was due to the lack of opportunities for students to conduct an open-ended type of investigation, and hence to develop the related process skills. The following extract from the interview contains an elaboration of her views.

> *"Since the worksheets have clearly defined questions that require only fairly short answers, students were unfamiliar with such type of open-ended questions, which required them to write out the whole plan and made tables of their own.... They were not required to draw tables previously. Tables are usually prepared for them. They were simply not taught to draw a table. Moreover, they got only a weak concept of controlling variables as there were only a few activities that trained them in this respect ......Similarly, students had done little in evaluating experimental design because most of the time was devoted to implementing the procedure of the activity. Students had tried to design investigation on their own but for only once. I think they need continuous engagement in such kind of investigative activities before real improvement can be seen."*

Fong also saw the results partially related to her students, which she described as too passive and weak in thinking.

> *"I have a feeling that the students were still quite passive. There is a need to strengthen their thinking skills, ... they would need more training on the writing of procedures and recording data. My students always wish me to tell them what to do. I*

think we need to change that situation."

Similarly, Keung (School 4) explained there was little improvement in items concerning controlling variables and designing experiments in the paper-and-pencil tests, and in most of the questions in *Solutions*, because of insufficient coverage of those particular aspects in his class. He noticed that their textbook did not place much emphasis on controlling variables except for the first chapter, so less improvement would be shown. ....He explained that it was a common problem that students were poor in answering open questions even for those that were very responsive in class. To solve this problem, Keung said teachers were caught in a dilemma.

"We don't want to cut down the content but it seems that we are under an increasing demand to improve students' process skills."

Noticing students performed most poorly in evaluating their own investigation design, Keung saw Chinese culture as the root of the problems.

"It may be the characteristics of Asians who tend to obey authority, irrespective whether it is correct or not. It is hidden in the Chinese culture that we shouldn't challenge the authority. If the culture encourages the spirit of scientific inquiry, for instance, the people could ask why and challenge the authority, then it will be more conducive to science learning. On the other hand, I think these cultural and societal factors are more influential than what they experienced in the secondary school. As they were accustomed to being spoon-fed and discouraged by their primary school teachers to query, you cannot expect them to develop critical thinking and evaluate experimental design. So the easiest way out is to write "no change" as the answer... I cannot see a healthy trend in Hong Kong students. Most are lacking in responsibility, indulging in fads, like pop singers, etc. The social environment is to bear the responsibility."

7.4.2 Attitudes and science self-concept

The four teachers were rather uncertain about the possible causes for the change in students' attitude and science self-concept. Ching's class showed a more positive gain in attitudes toward science and science curriculum in the new curriculum than the old curriculum, but a more negative gain in science self concept in the new curriculum. She explained the results as follows:

"The gain in attitudes of the students might be related to the emphasis on students' investigation in the new curriculum which enhance students' attitudes. But because of the difficulties students encountered in learning using this approach, they might have doubts about the own ability leading to the slight decrease in science self-concept in comparison to the positive gain in this attribute under the old curriculum."

In the case of Keung, his class in the new curriculum showed deterioration in all three attitudinal aspects when compared to the old curriculum. He shared similar views as Ching that such results might be due to a higher cognitive demand on students.

"The old curriculum was teacher-centred, so to students, what the teacher said was perfect. But now we withhold the answers from students, and encourage them to think. They might then realize science could not provide perfect answers. The same reason may apply to their science self-concept, which was more negative than the old curriculum group. This is because students might lose their confidence if there were too much thinking but without secure answers."

Fong and Yan seemed to be more puzzled by the greater deterioration of students' attitude toward science when compared with the old curriculum group, which deviates from their expectation. While Yan could not figure out a reason, Fong made the following comment:

"All I could say is that students' expectation is not necessarily consistent with our expectation. There could be a host of factors influencing their expectations."

As to the gender differences in performance in process skills and in attitudes toward science and in science self-concept, which were found to be statistically significant, all teacher interviewees shared the view that boys liked to think more than girls, hence the new curriculum was likely to favour boys. The following extracts reflect their views.

Keung: "I wasn't surprised that boys performed better than girls in the new curriculum because girls are better in memorization but that's what the new curriculum try to de-emphasize."

Yan: "The boys were willing to think, and the new curriculum could train them to think, therefore they would like it better. Girls would like to follow your instructions. They would do what you told them to. They'd rather follow your way of doing things."

7.4.3 Discussion

A common theme emerged from the teacher interviews is that students were not provided with enough experience in carrying out investigations, hence limiting their development of process skills. Students rarely had opportunities to design experiments by themselves and work according to their design. If ever conducted, these activities were manipulated to a great extent by the teacher. This also explains why students were poor in evaluating investigations because they had no ownership in their work, hence they had no motivation to reflect on it. At the same time, the development of communication skills were not emphasized due to reliance on worksheets which did not train students to make complete records. The teachers too recognized that this type of approach in going about investigations had created an undesirable effect of reinforcing students' reliance on teachers. This reliance on teachers may be rooted in both school and societal culture in Hong Kong which encourages spoon-feeding and obedience to authority.

The teachers were rather struck by the deterioration of students' attitudes and they found it difficult to arrive at any convincing answers. A possible reason suggested by the teachers was that the new curriculum proved to be more difficult to the students. They hypothesized that the gender difference was due to differences in learning style between boys and girls. Girls seemed to prefer to follow teachers' instructions and liked memorization, whereas, boys liked to think more by themselves.

7.5 Summary

To answer the third research question, with the implementation of the new curriculum, students showed significantly greater gains in process skills compared with their counterparts in the old curriculum. Yet, this applied more to skills of less complex types than to the more complex ones. Students showed greater deterioration in attitudes toward science, and poorer attitude toward science curriculum at the end of the year. No conclusive results were obtained about the effect of the new curriculum on students' science self-concept. Further, girls seemed to show less improvement in process skills and greater deterioration in attitudes and science-self-concepts than boys.

In the final chapter, I will summarize the research findings with respect to the first three research questions, leading to an answer to the fourth question. I will also discuss the significance of this study and what further research this study would suggest.

Chapter 8: Discussion and conclusion

8.1 Overview

This thesis has illuminated the reform of Hong Kong in science education at the junior secondary level. In this chapter, I summarize the answers to the first three research questions and discuss further insights which the findings provide with reference to the literature reviewed in Chapter 2 and 3. I hope these insights will cast new light on the literature and enrich our understanding of science curriculum reform and evaluation. Based on these, I will respond to the fourth research question – What are the implications of the research findings for the continuous implementation of the new curriculum? Finally, I will discuss the limitations as well as the significance of this research, and suggest issues that may need further exploration.

8.2 Research Question 1

What is the context of the reform and what makes the new curriculum distinct from the previous curriculum?

The responses to the sub-questions under this research question as discussed in Chapter 5 are summarized here. The response to Sub-question 1.3 is subsumed in Sub-questions 1.1 and 1.2.

Sub-question 1.1

What is the context of the reform, and the principles and theoretical underpinnings that guide the development of the new junior secondary science curriculum?

- The reform can best be viewed in a personal, social and educational context. It arose from dissatisfaction with the old curriculum in meeting increasing demands for scientific literacy in future citizens, and in helping students acquire the thinking skills essential for developing scientific knowledge. It was supported by the Hong Kong government's policy of changing the classroom language from English to Chinese for most schools assuming using the mother tongue could facilitate the implementation of the investigative approach (Section 5.2.1, p.58).

- There is an intention to shift the guided discovery approach to the investigative approach based on hypothetical-deductive reasoning (Section 5.2.2, p.156).

- Investigations are considered effective in enhancing self-confidence in learning science, and to lead students to appreciate the nature of the development of science knowledge (Section 5.2.1, p.158).

- The contents is designed to enhance students' perceptions of the relationships between science and everyday life, thereby enabling students to make informed decisions concerning science-related social issues (Section 5.2.1, p.157).

- The change from a highly prescriptive to a less prescriptive one would, hopefully, increase the variety of textbooks, and encourage teachers to cater for students of different abilities (Section 5.2.2, p.160).

<u>Sub-question 1.2</u>

How did curriculum planners translate their perceptions of reform into the official curriculum document?

- A wider variety of teaching approaches and more relevant content areas are evident in the new syllabus (Section 5.3.3 & 5.3.4, p.173).
- Teacher-led practical work with dual emphasis on concepts and less complex skills and techniques remains the dominant type of activities (Section 5.3.4, p.175).
- Students are expected to develop a wide range of process skills relevant to hypothetical-deductive reasoning. Yet, the skill of evaluating experimental design is surprisingly omitted in the syllabus. (Section 5.3.2, p.171)
- Development of skills is seen as a stepwise process, leading ultimately to skills integration in open-ended investigations. The ability to conduct investigation is perceived as the pinnacle of science processes (Section 5.3.4, p.180).
- The number of open-ended investigations is limited due to safety concerns and lack of suitable choices (Section 5.2.3, p.161).
- Opportunities for the average student to participate in open-ended investigations are further limited as substantial parts are treated as extension for more able students (Section 5.3.4, p.181).
- More specific guidelines on assessment are lacking in the syllabus (Section 5.3.5,

p.182).

As discussed in Section 5.4, the present findings show that the planners had a strong intention to align Hong Kong's science curriculum to the world trend, emphasizing social relevance and scientific investigations to help students develop skills and experience science as an important and unique means for generating knowledge. This motive is consistent with Black's and Atkin's (1996) argument that the foremost justification for reforms were based on new conceptions of learning which the reformer hopes to bring into the classroom (Section 2.3.1, p.31).

Yet, the more specific driving forces for the present reform are quite different from our neighboring Asian countries, which concern primarily the development of science and technology as a national priority on top of developing scientific literacy for all. The present reform is meant to serve personal and social needs rather than political or economic causes. This may be attributed to the fact that Hong Kong is neither a sovereign state, nor is its economy relied on its own research and development in science and technology (Section 1.2.1, p.15). Despite this, the present reform was made possible by a change in the language environment in post-colonial Hong Kong. In the light of the increased applications of science and technology in our everyday lives and their implications for society, it seems justified to design a new curriculum that emphasizes development of scientific literacy in our future citizens.

Another dimension to this personal/social context of reform is that the curriculum planners would like to make the curriculum less prescriptive and introduce more diversified teaching approaches to cater for a wider range of abilities. This makes the new curriculum more "inclusive", which is in line with the trend observable in other countries (Section

2.3.4, p.39), as well as holding teachers more accountable for tailoring their teaching to meet students' needs.

In order to predict how likely the intended curriculum could achieve its objectives, it is worthwhile revisiting the four characteristics of curriculum change, namely need, clarity, complexity and quality/practicability, as suggested by Fullan and Stiegelbauer (1991) (Section 2.4.1, p.58), and to discuss how the new curriculum measures against these parameters.

There is apparently a "need" for reform in the light of the problems inherent in the old curriculum and the new personal and societal needs. This was indicated by the fact that teachers in general considered the new curriculum as an improvement over the old one (Section 6.3.5, p.207). Despite this, findings of the teacher interviews show that teachers did not seem to perceive any urgent need for changing their existing practices since the new curriculum is not accompanied by a high stake assessment that matches its emphases, or any stipulations of assessment practices with which they have to comply.

As to "clarity" of the change, the syllabus was clearly written but some areas such as assessment methods are open to interpretation. The suggestions contained in the syllabus seem to be too general and lack concrete guidelines to demonstrate to teachers how the suggestions could be put into practice (Section 5.3.5, p.182). Although it may be the planners' intention to allow teachers to select assessment practices appropriate to their specific school and classroom context, the vagueness of the new assessment requirements may create two possible effects. The first is that teachers may be uncertain as to the requirement and hence may find implementation difficult. The second possible effect is to create a situation of "false clarity", which occurs when change is interpreted in an oversimplified way (Fullan 1991). As suggested by the teacher survey and interview data, the first effect seems more important in inducing a gap between the documented curriculum and the teachers' perceived curriculum.

Regarding the issue of "complexity", since the investigative approach and other unconventional teaching approaches were relatively new to science teachers, they might need to acquire new knowledge or even to alter their existing beliefs. Researchers have pointed out that the concepts behind scientific investigations are complex and necessitate a new understanding by teachers (Millar, Lubben et al. 1994; Gott and Duggan 1998). The "complexity" of the investigative approach is to a certain extent reflected by the perceived need of teachers to develop pedagogical skills in leading investigations and to acquire knowledge about the investigation process (Table 6.13 in Section.6.3.4, p.199).

The "quality/practicability" of the documented curriculum seemed to be compromised by the relatively limited opportunities for students to pursue genuine investigative work due to safety concerns and lack of "suitable" choices. As this type of work seeks to integrate science process skills in a holistic way for solving scientific problems, students deprived of such opportunities are less likely to achieve the stated aims of developing "the ability to enquire and to solve problems" (HKCDC 1998, p.3.)

I would argue that the planners' strategy for teaching process skills may also undermine the "quality/practicability" of the new curriculum. As discussed in Section 5.3.4, (p.179-180), the strategy is to lead students to develop skills through both teacher-led practical activities and open-ended investigations. Each of these two approaches has its limitations in the way they are designed in the syllabus.

The first limitation is that all teacher-led practical activities have the dual purpose of imparting concepts as well as developing individual skills as discussed in Section 5.3.4, (p.179). Yet, this arrangement is likely to constrain genuine skill development. Taking the skill of "observing" as an example, if the very act of observing is to elicit a particular concept, the observation process will become theory laden or biased. This is not too much of a problem because even scientists made observations under the guidance of theory. The problem is that in the present case it is the teacher rather than the students who would dictate what to observe, thereby placing students in a passive position. This drawback has led to the argument that school practical work should be separated from the demands of displaying the theory (e.g.Woolnough and Allsop 1985). This applies to other skills as well. Millar and Driver (1987) have argued that the results of school experiments, like some classical experiments on tropism, are not clear cut or decisive enough to provide any real test of hypotheses, leading them to suggest that school experiments could not be used hypothetico-deductively in developing classical concepts in students.

Underlying this coupling of skills with teacher-led practical activities seems to be the logic that individual skills should be taught separately before integrating them in investigations (Section 5.3.4, p.180). However, the history of scientific development tells us that scientists did not necessarily learn all those processes before they applied them to solve problems. In fact, scientists often apply tacit knowledge to solve problems (Polanyi 1966, cited in Toh and Woolnough 1993). By the same token, students may not need to learn all these skills one by one before they could generate problems and suggest ideas to be tested. This argument is supported by evidence from research (e.g. (Roth and Roychoudhury 1993; Toh, Boo et al. 1997).

The second limitation is related to the way that open investigations are set out in the syllabus. About half of these activities are treated as extension activities for more able students. As indicated by the findings of teacher interviews, this strategy has created an undesirable effect of marginalizing investigations in science classes. Yan's case was a good example. She chose not to implement these activities because she perceived them as non-core and could be omitted if time was insufficient. (Section 6.4.2, p.219).

8.3 Research Question 2

Do teachers implement the new curriculum as intended by curriculum planners, particularly with respect to the use of the investigative approach?

The responses to the sub-questions are summarized as follows:

Sub-question 2.1

How do teachers perceive the new curriculum? To what extent are teachers' perceptions in line with the intended curriculum?

- Teachers perceived a greater change in teaching approaches and approaches to practical work than in content and modes of assessment. They tended to agree that the content areas were made more relevant to everyday lives (Table 6.2 & 6.3, Section 6.3.1, p.190)

- The emphasis on the nature of science was not adequately perceived by teachers, nor was the importance of investigative activities in developing students' self-confidence in scientific inquiry (Table 6.3, Section 6.3.1, p.191; Table 6.21, Section 6.3.5, p.206)

- There were variations in teachers' familiarity with the intended curriculum due to variation in sources and amount of input (Table 6.1, Section 6.3.1, p.190; Section 6.4.5, p.231).

- Teachers tended to attach different degrees of importance to different emphases of the curriculum and to focus their teaching accordingly (Section 6.4.5, p.232).

Sub-question 2.2

How does the implemented curriculum differ from the intended curriculum teachers perceive?

- Teachers tended to change their teaching practices according to the change they perceived in the intended curriculum (Table 6.5, Section 6.3.2, p.192).

- The coverage of investigative activities was relatively low. This was attributed to factors like inadequate laboratory periods, large class sizes and content overload (Table 6.7 & 6.8, Section 6.3.2, p.193)

- Teachers tended to provide close guidance to students while conducting investigations due to their perceived lack of ability in students, avoidance of discipline problems, concern about time limitations and a desire to maximize benefits for students. (Table 6.9 & 6.10 in Section 6.3.2, p.194)

- Laboratory activities were perceived by students as teacher and worksheet-directed with little demand for them to record in a detailed and authentic manner. From the perspective of students, they rarely performed open-ended investigations that were comparable to *Solutions* (Section 7.3.2, p.269)

Sub-question 2.3

What opportunities and constraints are present? How do these opportunities and constraints affect implementation?

Constraints:

- Four types of constraints were identified: school organizational factors (class size, lack of class and laboratory periods); curriculum factors (overloaded content); student factors (lack of student ability and discipline problems); and teachers' factors (degree of mastery of the new teaching approaches and excessive workload) (Section 6.3.3, p.195).

- The above factors may be attributable to school's examination-oriented culture and, possibly, to Chinese culture that emphasizes obedience to authority (Section 6.5, p.236).

- There were problems in making training opportunities accessible to teachers (Table 6.12, Section 6.3.4, p.198).

- Teachers perceived that they were not adequately prepared for implementing the new curriculum. Some teachers were rather unconfident of leading investigative activities, in particular female teachers and those that were less experienced. Teachers felt they needed training especially in skills for leading investigations, knowledge of the investigation process and the use of non-conventional teaching strategies (Table 6.13, Section 6.3.4, p.199).

- Differences in teachers' change in practice may be related to teachers' attitudes and commitment, and to their mastery of the necessary knowledge and skills (Section 6.4.5, p.234).

Opportunities:

- Teachers were generally convinced that the new curriculum was an improvement over the old one, yet they were unsure whether it could enhance students' motivation and attitudes toward science (Section 6.3.5, p.202).

- Teachers who practised to the intended curriculum tended to be more optimistic about the benefits of the new curriculum than those who did not (Table 6.23, Section 6.3.5, p.208).

- Teachers in CMI schools evaluated the achieved curriculum more positively than their counterparts from EMI schools, implying mother tongue teaching facilitates learning in the new curriculum (Section 6.3.5, p.209).

- The training provided by the CDI was regarded as useful (Section 6.3.4, p.198).

The findings underscore the importance of the teacher in the reform process which is consistent with literature (e.g. Fullan and Stiegelbauer 1991; Snyder, Bolin et al. 1992). It was shown that teachers needed time to adapt to the new content and teaching approaches. Although Schemer's (1991) argues that it should not be assumed that a teacher would necessarily adopt a new programme even if he or she fully understands it (Section 2.4.2, p.63), the present findings suggest that teachers tended to change their teaching practices according to the change they perceived in the intended curriculum. Moreover, the greater the degree of change in practice, the more likely that teachers would perceive improvement. Thus, it appears that teachers being familiar with the reform and their actual adoption of the intended practices determine, at least partly, their judgement about improvement of the curriculum.

In line with the CBAM model (Section 2.4.2, p.64), the four teacher interviewees seemed to have progressed to different stages of concern, indicating they adjusted differently to the change. Yan had probably progressed only up to Stage 2 as she was still rather uncertain about the demands of the reform and her new roles. Keung seemed to be at a point between Stage 2 to 3 as he was very much concerned with the conflicts between the reform and the existing structures but was trying to manage the change. Fong should have progressed to Stage 3 or beyond as her concern was more with managing change, and making the best use of information and resources in preparing for her teaching. Ching seemingly had reached the highest stage among the four. She was probably at Stage 4 to 5 since she was concerned with the relevance of the reform for her students, and on evaluation of her student outcomes. She was also aware of the need to cooperate with her colleagues in bringing about genuine changes such as introducing new assessment practices.

Common sense tells us that teachers will move closer to the intentions of the curriculum when they begin to master the "complexity" of the new practices. Yet, the present findings seem to suggest that some of the teachers' existing practices may not necessarily change with the passage of time. An issue in question is that not many teachers would allow their students to conduct open-ended investigations with minimal assistance. The teachers' argument that students lacked the ability to conduct investigations was, strictly speaking, not supported by literature, nor by the present findings. Linn, Chen et al. (1977) subjected 5th and 6th Grade American students from a racially mixed lower-middle-class area to investigations in a free-choice environment. Their findings show that students could operate responsibly in such an environment and consistently carried out investigations at their expected intellectual level. The teachers also reported that a large number of students could successfully pursue independent investigations. Toh and Woolnough (1993) also found out that 13^{th}-year-olds Singaporean students were able to use tacit knowledge to carry out investigation to a large extent.

In the present study, most teachers interviewed never tried to lead genuine investigations in their class, hence students' lack of ability could not be confirmed. Yet, pre-test results of the quasi-experimental study indicate that even before the course, Secondary 1 students were not short of ideas in approaching the TIMSS tasks though they had yet to master the skills (Tables 7.10 and 7.11 in Section 7.2.2, p.251, 254). Moreover, TIMSS performance assessment tasks were in general well received by the student interviewees who found them challenging and enjoyable (Table 7.20 in Section 7.3.2, p.271).

Based on the above arguments, I postulate two basic causes for the "conservative" practice of teachers in the use of the investigative approach. First, teachers' practice was due more to their lack of confidence in their students. The reasons for this are worthy of further exploration. It might reflect teachers' lack of experience or knowledge in facilitating students to investigate without close supervision since they were so used to teaching using the guided discovery approach. Teachers conceding that they needed training in investigation and in its pedagogy seems to support this assumption. Taking all these into account, teachers' perception of their student ability was probably a projection of their own difficulties. However, further research is needed to confirm this inference.

The second basic cause underlying teachers' practice is probably inherent in teachers' perceptions of the nature of science and their role as science educators. Teachers' perception that closer guidance could reduce time and was more beneficial to students implies that they were still accustomed to the role as a deliverer of knowledge and skills, rather than as a facilitator seeking to empower students to inquire and develop skills in a self-directed investigation. The perception of role is evidenced in the finding that most teachers did not regard "enhancing students' self confidence and self-assurance" as an important benefit of investigations compared with other objectives (Table 6.21 in Section 6.3.5, p.206).

I would argue that these two basic causes are inter-related. Teachers' perceived role as a knowledge and skill provider has gradually eroded teachers' confidence in students' ability to inquire, leading to a vicious circle. Since students have little freedom to investigate, their skills are not well developed, making them more unconfident of their own ability to investigate. This in turn reinforces teachers' belief that students lack this ability, thus further undermining their chances for learning the essential skills. This is more likely to be so if the school places great emphasis on discipline control as in School 3 (Section 6.4.4, p.231).

Findings of the teacher survey and interviews both suggest that teachers' practice was influenced by the school's examination-oriented culture which stressed only knowledge and understanding. Another argument is that the poor ability of students in conducting investigations, in particular evaluating designs, was attributable to Chinese culture that stresses obedience to authority. These findings echo other researchers' argument that culture could be a restraining factor for reform (e.g. Prophet 1990; Ogawa 1998, Section 2.4.1). The possible influence of Chinese culture on the learning of science should be studied in a more in-depth manner before a firm conclusion could be drawn.

8.4 Research Question 3

Is there any evidence of improvement in students' process skills and attitudes toward science on completion of the first year of implementation when compared to the old curriculum? And, to what extent is the science self-concept influenced by the new curriculum?

Sub-question 3.1

How do students' process skills, attitudes toward science and science curriculum, and science self-concepts change in the first year of the implemented curriculum?

Sub-question 3.2

How does the new curriculum compare with the old in terms of students' achievements measured by the parameters mentioned in Sub-question 3.1?

The responses to the two sub-questions are summarized together as follows:

- Students in both the new and old curriculum groups made significant improvements in process skills through the academic year, with the new curriculum group showed a greater overall improvement (Table 7.4, 7.7 & 7.8, Section 7.2.2, p.241-245)

- Improvements in process skills were restricted mainly to less complex skills, like gathering and presenting data. There was little evidence of improvements in more complex skills like designing experiments, controlling variables and evaluating experimental designs (Table 7.9-7.11, Section 7.2.2, p.249-254).

- More able students showed less improvement than less able ones in both the new and old curriculum groups (Section 7.2.2, p.248).

- There is little evidence that the new curriculum improved students' confidence in performing independent investigations more than the old curriculum (Section 7.3.2, p.274).

- Contrary to teachers' expectations, students' attitudes toward science deteriorated more in the new curriculum group than in the old group (Section 7.2.4, p.256).

- Both curriculum groups showed similar degree of deterioration in students' attitude toward science curriculum (Section 7.2.5, p.259).

- Change in students' science self-concept varied among teachers, suggesting the influence of factors other than the curriculum itself (Section 7.2.6, p.261).

- In the new curriculum group, gender difference was observed in process skill performance in favour of boys (Section 7.2.2, p.248).

- In the new curriculum group, girls recorded a significant deterioration in attitude toward science (Section 7.2.4, p.258). Their science self-concept was also significantly lower than boys towards the end of the year (Table 7.19, Section 7.26, p.263)

From the answers to RQ1 and RQ2 summarized above, the limited improvement in more complex skills like planning and evaluating investigations was attributable to the insufficient engagement of students in open-ended investigations. This is partly due to a deviation of working/practiced curriculum from the intended curriculum, and partly to the inadequate provisions of open investigations in the syllabus and the under-emphasis of the skill for evaluating experimental work. Yet the increased deterioration of attitude toward science and science curriculum under the new curriculum was quite unexpected. Teachers suggested that students might find it more difficult than the old one. This is in line with the findings that students' expectations are not necessarily consistent with teachers' (Wilkinson and Ward 1997) The finding that the more able students in both curriculum groups made less improvement in process skills compared with the less able ones is consistent with the results of TIMSS as discussed in Section 2.5. TIMSS results indicate that even the best Hong Kong students performed more poorly than their counterparts in top-performing countries like Singapore (Law, 1996). The present findings suggest the reason may be that the brighter students were not adequately challenged in using more complex process skills as evident in the general lack of improvement in those items (*Solutions*). This finding is common to both curriculum groups, indicating that the new curriculum has not improved the situation (Fig. 7.8 & 7.9, p.253; Table 7.10, Section 7.2.2, p.251).

The present study indicates that boys performed better than girls in process skills. This lends further support to gender difference in science achievement in Hong Kong junior secondary schools (Tsoi 1981, Holbrook 1990, Law 1996). The new curriculum did not appear to narrow this gap. The deterioration of students' attitude toward science is in line with research findings that students' attitudes might decline with increasing grade level (Schibeci 1984), or from the beginning to the end of a science course (Wideen 1975; Baker and Piburn 1991). Yet, the greater deterioration in student attitudes in the new curriculum group compared with the old one is a cause for concern, given the plentiful evidence of positive influences of laboratory-oriented science instruction on student attitudes toward science (Milson 1979; Saunders and Dickinson 1979; Freedman 1997).

Although a meta-analysis of literature from 1970 to 1991 on gender differences show that boys consistently displayed a more positive attitude toward science than girls (Weinburgh 1995), the deterioration was more serious for girls in the new curriculum group than those in the old group. In addition, girls in the new curriculum group showed greater deterioration in science self-concept than boys. All these seem to indicate that the present reform may not be in favour of girls at least in the first year of implementation.

There is no indication from the present study that students' self-confidence in tackling open investigation has improved in the first year of the new curriculum compared with the old curriculum. Students of both curriculum groups expressed a lack of self-confidence in investigations because of the uncertainties or ambiguities in the process. This may be attributed to teachers' persistent use of a guided approach in leading students through practical work. Toh, Boo et al (1997) have already criticized the guided discovery approach severely for obstructing the development of students' ability to perform investigations:

> *"Yet most students go through a science program of guided discovery, making use of worksheets. Tables are pre-drawn and students are expected to enter their observations/measurements in the tabulated format provided. In this environment where ambiguity has been taken out, students may not be prepared for problem-solving and abstract thought. Solution and conduct of an "investigation" are pre-planned with a particular algorithm by the teacher. Students are not expected to plan the investigation for themselves, or to decide what to investigate for themselves. In other words, students are not entrusted with situations of ambiguity. They would therefore not develop that tolerance for ambiguity. Students who are raised on a diet where all ambiguities have been removed will no doubt be handicapped when confronted with such situations.'(Toh, Boo et al. 1997)p.139*

8.5 Research Question 4

What are the implications of the research findings for the continuous implementation of the new curriculum?

From the analysis of the first three research questions, I set out to answer my last research question. There were some encouraging signs of change. Teachers were generally able to identify with the new goals and they considered the relevance of the curriculum to everyday lives, and the new approaches of teaching and practical work particularly worthwhile. Teachers' positive attitudes toward the reform and the evidence of improvement shown by students in the use of less complex process skills seem to justify the reform and its continuous implementation. Despite these, the present findings have specific implications for the intended, implemented and achieved curriculum, which need careful attention before the reform can emerge as a fruitful one.

8.5.1 The intended curriculum

From the findings of the teacher survey, the use of mother-tongue teaching seems to facilitate the implementation of the new curriculum. Further evaluation may need to be carried out to confirm this inference. If the advantage of mother-tongue teaching can be confirmed, this will raise doubts about the desirability of teaching the new curriculum in English in EMI schools.

The new curriculum attempts to redress the balance between conceptual learning based on guided discovery, and process-oriented learning based on investigation. The present findings indicate that the balance was still tilted toward the former. The strategy for developing processes may need to be reviewed to bring open-ended inquiry to a more central position, and to decouple skill development from the teaching of concepts to a greater degree. This is not to say that processes should be taught in isolation of knowledge. As evidenced in literature, it may be more helpful to focus the development of process skills around more genuine and open inquiry that aims to extend students' scientific knowledge rather than to rediscover well-documented concepts. These changes should help to improve the scope of investigations in schools, hence providing more opportunities for students to develop genuine, non theory-laden inquiry and problem-solving skills. Moreover, by encouraging students to assume responsibility for investigation (Hodson 1998), more complex skills such as evaluating one's own experimental design, which is not even mentioned in the syllabus, can be developed. Reference may be drawn from the National Curriculum of New Zealand and the National Standards of the USA, which are focused towards this direction (Section 2.3.5, p.46-50). However, in doing so, teachers need to bear in mind the possibility that class and pupil characteristics may influence the effectiveness of certain teaching strategies (Crocker, Bartlett et al. 1976).

From the findings of the intrinsic analysis of the syllabus and from the teachers' feedback, the proposed changes to assessment were not distinctive and detailed enough to support implementation. Given the "what-gets-tested-is-what-gets-taught" syndrome (Snyder et al 1992 p.420), change in classroom practice is not easy to achieve. Most teachers would continue to stick to the old rule of assessing students' knowledge through paper-and-pencil examinations. This implies that more detailed and prescriptive guidelines on the new assessment methods should be made available to teachers.

In addition, training on the use of new assessment methods is also a must. This should aim to change the examination culture prevailing in Hong Kong schools in order to catalyze change in classroom practices. I am not sure whether the introduction of a high-stake assessment is an appropriate direction to take in the light of public sentiments in Hong Kong against additional public examinations for fear of encouraging more spoon-feeding and coaching. Perhaps, a school-based assessment scheme may be more feasible in the context of Hong Kong schools. This assessment scheme could focus on a few crucial aspects like investigation skills and could be administered by individual schools with the support of the CDI and teacher training institutes.

8.5.2 Implemented curriculum

Despite the fact that the implementation of the new curriculum may continue to improve as teachers accumulate experience, there are a number of hurdles to overcome. Sydner, Bolin et al (1992) argue that it may be less important to ascertain the degree to which the change is implemented as planned than to study how teachers interact with the intended change and identify factors that facilitate or hinder implementation. The present study shows that the curriculum planners understood the limitations of teachers in implementing the curriculum in the classroom like lack of time, large class sizes, and insufficient laboratory periods (Section 5.2.3, p.164). However, these issues were not addressed adequately in the planning and implementation stages. In fact, some of these issues, like large class size have been identified since the Scottish Integrated Science was first introduced to Hong Kong (Section 3.3.3, p.105). While it is unlikely that class size will be reduced in Hong Kong schools in the near future, practical advice or training on how investigations could be carried out in the classroom context of Hong Kong schools is of utmost importance. This should involve strengthening of teachers' planning, management and communication skills to help them engage their students in meaningful investigative work. In addition, there is also a need for teachers or curriculum planners to set priorities and tailor the curriculum contents to fully utilize the limited time and laboratory periods available without sacrificing the use of the investigative approach.

As discussed in Section 8.3, it appears that the implementation of the investigative approach was influenced by the perceived role of teachers. Hence, there is a need for teachers to change their role from a "deliverer of knowledge and skills" to a "facilitator" who can empower students to undertake independent genuine inquiry. Failure to achieve this role shifting will perpetuate the drawbacks of guided discovery. Research by Tal, Dori, et al (2001) has already called for changes in teachers' role in curriculum reform. They argue that teachers should change their role from one of knowledge providers to that of learners in the implementation of curricula adopting the Science-Technology-Environment-Society approach.

The question is "How do curriculum planners expect to spark positive interest and receptivity in teachers?" (Schremer 1991). Snyder, Bolin et al (1992) provide the clue that "commitment of teachers usually developed through the actual use of materials, rather than being a prior condition". Lazarowitz's (1976) demonstrated that American secondary science teachers using inquiry-based curricula had more favourable attitudes toward inquiry strategies than non-users. In line with these, the present findings demonstrate that the degree to which teachers changed their practices correlated positively with teachers' perception of improvement. All these imply that merely telling teachers to change will not be fruitful. Curriculum planners or teacher trainers should engage teachers to try out the investigative approach in their own classroom with adequate initial support to help them develop commitment and positive attitudes toward the reform.

8.5.3 Achieved curriculum

The findings from the teacher interviews show that the old practice of using paper-and-pencil examination to assess students' academic knowledge still prevailed in the classroom. Assessment of skills was uncommon despite the implementation of the reform. This has a backwash effect on the new curricular emphases because teachers would continue their practice of teaching students for passing traditional examinations. It is difficult for teachers to take individual actions because changes in assessment policies would necessitate coordination of the whole teaching team and laboratory technicians. Nonetheless, if teachers could build up a good collegiate atmosphere as in School 1 (Section 6.4.1, p.216), positive change can occur. Engaging teachers to work as a team for realizing the new aims is an issue worthy of exploration by school heads, science panel heads and curriculum planners.

Student interviews proved to be a useful tool for eliciting students' perceptions of the curriculum and the reasons behind their weak performance, using TIMSS assessment tasks as a focus. Students in general found these assessment tasks more interesting and challenging than the practical work they had done in class, indicating that they would like to have more opportunities for conducting this kind of activity. Their response is remarkably similar to the positive reaction of UK students to the Standard Assessment Task (SAT) during its pilot stage as reported by Jennings (1995). Jennings also concluded that the SAT investigations had contributed to a growing confidence in teachers that investigations could be managed in the school laboratory. This suggests that assessment could have positive influence on teaching practices, and that investigations are feasible and manageable if there is adequate planning in advance.

The findings on gender differences in terms of process skills performance, attitude toward science, and science self-concept need to be confirmed by further research. If proven to be the case, it is deemed necessary to inquire into the intended or the implemented curriculum to identify possible causes for the biases against females in both process skills and attitude development. If, as suggested by the teacher interviewees, this was due to difference in learning styles which caused males to outperform females in the new curriculum, it would be important to devise strategies to help female students to benefit fully from the present reform.

8.6 Limitations of the study

Given the many constraints such as a rigid time frame and limitation of manpower typical of a lone researcher, the present study inevitably suffers from the following limitations.

a) The present study, which relies on nonequivalent control-group design, is no comparison with true experimental study. Yet this seems to be the best alternative in the present context. Threats to reliability and validity were minimized as far as possible by purposive sampling, matching of classes in the two curriculum groups, and through applying statistical methods (ANCOVA). Despite these, caution is needed in generalizing the present findings to all CMI schools in Hong Kong.

b) The present study relied mainly on indirect methods to obtain evidence about teacher implemented practices, for example, teacher survey and interviews. Although the primary aim was to obtain a macro-view of the curriculum from planning to the achievement of outcomes, it inevitably missed some of the information that direct methods like classroom observation could offer.

c) In the quasi-experimental study, science skills were assessed primarily in the context of practical investigation using primary data source. Hence, this study provides no information on students' ability to inquire using secondary data sources.

d) Ideally, to reflect fully the consistency between different levels of the curriculum, data collected from one level should illuminate the methods of data collection used for the next as advocated by Parlett and Hamilton (1977, Section 3.2.2, p.84) and Van Aaist and Wierstra (1979) (Section 3.3.2, p.103). However, because of the rigid time frame of the study, some of the methods and instruments had to be designed before the collection of more in-depth data. For example, the pre-test of the quasi-experimental study took place before the curriculum planners were interviewed. Hence, in the earlier part of quasi-experimental study, the documented curriculum rather than the planner interviews was used as the major source of information. At the later stage, the design of methods like teacher questionnaires and teacher interviews could become more focused as they were informed by a richer data base collected at the preceding levels.

e) As in other evaluation studies, the very act of the evaluation might have influenced the data obtained in the process. Nevertheless, as indicated by the teacher interview data, the Hawthorne effect did not appear to have a significant influence on the teaching of the participating teachers. However, bringing students' outcomes to the awareness of the teachers during the second interview seemed to exert a notable effect on their responses. Some interviewees tended to consider overcoming their students' weaknesses as a priority in the coming year. This demonstrates vividly the powerful influence of curriculum evaluation on teaching practices.

8.7 Significance of the present study

Despite these limitations, the significance of this study can be viewed from three perspectives: the present curriculum reform in Hong Kong, principles of curriculum evaluation, and curriculum evaluation methodology.

8.7.1 Significance to the present curriculum reform in Hong Kong

As far as I am aware, this thesis is the first locally driven summative evaluation study on junior secondary science education in Hong Kong. It capitalized on a unique time frame such that the transition from the old curriculum to the new curriculum could be critically examined. Instead of a mere comparison of the relative merits of the two curricula, the present study set the evaluation in a broader context to explore the driving forces for the reform and its theoretical underpinnings. This allows the present reform to be viewed against the world-wide trend of science curriculum reforms. The lessons learnt from past reforms could help inform us on the possible opportunities and pitfalls of the present reform, and to put the present research to a better focus.

Some of the findings were predictable, for example, constraints due to large class size and overloaded content. Yet the study helped to unveil factors that are more deeply seated, like the problematic strategies for developing investigation skills, the seemingly misconceived role of teachers in teaching science under the new curriculum, and the possible cultural influences. These findings serve to extend our understanding of the determinants of science curriculum reform, particularly in the context of Hong Kong.

Thus, this study urges curriculum planners to reexamine the curriculum design in order to improve the strategies for meeting the aims of the reforms. They are expected to be more sensitive to the constraints faced by teachers in meeting new demands. In addition, there is an urgent need for teachers to re-conceptualize their role as "school science educators" and to heed the aspirations of students for more challenging and meaningful activities in science classes. Teachers should recognize the need to generate self-initiative, creativity and interest in science lessons as advocated by Holbrook (1990) in response to Hong Kong's unsatisfactory performance in SISS.

This implies the important role of teacher training in the present reform. Teacher training should aim not only to develop teachers' pedagogical knowledge and skills but also to catalyze role shifting in teachers. There is a strong case that science teacher training in Hong Kong should adopt a more realistic approach. This means that apart from equipping teachers with the necessary knowledge and pedagogy of investigations, we should help teachers to master a repertoire of skills including management, communication and problem-solving skills, which are essential for putting the investigative approach into practice in their classroom. This more realistic and focused approach to training should help teachers progress from more "immature" stages of concern to more "mature" ones.

8.7.2 Contribution to the theoretical models of curriculum evaluation

This thesis is based on the evaluation framework employed in TIMSS, with the three-level conceptualization further differentiated into seven sub-levels. This refinement helps to reflect the intricacy of the curriculum process, and was proved to be of great value in guiding the design of research methodology and in eliciting more in-depth information at the three levels of curriculum. I illustrate this by revisiting some of these sub-levels I have studied.

The notion of the *conceived* curriculum has served to guide the evaluator to explore the intent of the curriculum planners beyond what has been laid down in the *documented* curriculum. This helped to shed light on the vision of planners and the influences behind the design of aims and the choice of teaching strategies. A case in point is that the present reform was catalyzed by the policy of mother-tongue teaching which was thought to provide a favourable environment for implementing the investigative approach. Feedback from teachers seems to indicate that mother-tongue teaching was effective. Yet evidence gathered at the sub-level of *working/practised* curriculum indicates that this new policy is only a necessary but not sufficient condition for the successful implementation of the curriculum due to the presence of other constraining variables.

The *teachers' perceived* curriculum was proved to be another important notion in the present model. It could be viewed as a bridge between the intended and the *working/practised* curriculum. This notion is important because teachers have first to make sense of the distinctive features of the reform from his or her own perspective before they could translate it into classroom practice. Its importance is evidenced in the strong positive correlation between teachers' perception and their degree of change in practices. Hence, to effect change in teaching practices, it is important to change teacher's perception in the first place. Study of the consistency between the *perceived* and *working/practised* curriculum has led to the identification of a range of superficial and deep-seated constraints that need to be overcome. All these findings testify the viability of the present evaluation framework in evaluating a centralized curriculum reform.

8.7.3 Contribution to evaluation methodology

The present thesis lends support to the use of both quantitative and qualitative methods to gather data in curriculum evaluation. Multiple methods involving different stakeholders have proved to be valuable in gathering essential data to illuminate different sub-levels of curriculum and the consistency between them. As such, the whole curriculum process could be viewed as a drama consisting of a series of acts, in which different groups of actors including curriculum planners, teachers and students come into play. Each group of actors told their own story, thus allowing a more complete picture to be drawn. Curriculum evaluation could be seen as a recapitulation of events from the perspectives of these actors. Data collected from different actors triangulated and supplemented the findings of each other, thereby enhancing their reliability and validity. The findings of some methods informed the design of the others, making the data collection process a more focused and illuminative one.

8.8 Areas for further study:

Based on the findings of the present study, further studies may be contemplated. These studies could serve three purposes: first, to carry out follow up research to study the longitudinal development of students as they progresses from Secondary 1 to 3; second, to study other aspects or sub-levels of the curriculum which are important but were not attempted in this thesis because of time and resource limitations; and third, to carry out in-depth studies on the problematic or ambiguous areas identified in the study and to reveal their possible causes.

To follow up this research, a longitudinal study spanning three years from S1-3 could be conducted to evaluate improvement in students' achievement through the whole junior secondary science course. This could provide a more comprehensive picture of the progression of students in such key objectives as development of process skills and attitudes. In order to further differentiate students' performance from one year to the next, more specific tools should be designed and tested. The criteria employed for testing student ability to use the investigative approach could be broadened to cover secondary data sources. Due to time and resource limitations, the present study did not evaluate the textbook curriculum. Yet the findings from student interviews indicate that there might be weaknesses in the textbooks particularly in the design of worksheets for experimental activities. Future studies may include textbook analysis for inquiring into the extent to which textbooks comply with the documented curriculum and how they are influencing teachers' practices.

The present study exposes some problematic or ambiguous areas, including a greater deterioration in students' attitudes toward science, and the lack of impact of the new curriculum on students' science self-concepts. Preliminary evidence from this study shows that these might be related to teacher factors. More in-depth studies are needed to delineate factors influencing these attitudinal attributes and the role played by the curriculum. This information is essential for improving these aspects of achievement. The other two problematic areas worthy of further exploration are gender differences in achievement in terms of skills, attitudes and science self-concept, and the possible problems associated with using English as the medium of instruction in the EMI schools, and how these could be remedied.

The present study underscores the importance of teachers in effecting changes. It would therefore be helpful to carry out studies into teachers' practices or behaviours in the classroom or laboratory. The aim is to identify teachers' characteristics that are conducive to improving students' achievement in specific areas like process skills attainment. Research may be conducted to identify the kinds of training opportunities useful for teachers to implement the new curriculum more effectively. Also, large-scale cross-sectional studies may be conducted to monitor changes in students' performance as more teacher training opportunities and additional resources input are provided.

Finally, an important area of research with more far-reaching consequences is to explore what kind of science curriculum would suit Hong Kong the best. In the present study, I have deliberately refrained from evaluating the worth of the curricular aims of the reform. However, it would be beneficial to Hong Kong in the long run to fit the goals of science education to its unique context. A starting point may be to review the so-called "cosmopolitan science", which Hong Kong seems to be aiming for, and examine how best it suits Hong Kong's needs.

8.9 Personal reflections on the study

A PhD thesis and curriculum evaluation are both demanding tasks. Yet I have combined both in this study. With retrospect, I feel I could have conducted this evaluation better if I had already completed my PhD, because then I would have gained enough experience to be a better researcher. Saying this is to underscore the complexity of curriculum evaluation this study was engaged in. This is one side of the coin. The other side is that undertaking this thesis probably enabled me to learn more than I could have because of the great demand the topic had put on me.

In my process toward the Ph.D., I have learned to organize my thoughts systematically because without doing so, I could not have managed to tease out the crucial aspects and organize them into my evaluation framework. A prerequisite to that was to achieve a deep understanding of the notions of curriculum and curriculum reform because without this, I would have built my evaluation framework on loose sand. The literature review has helped me draw references regarding both theoretical and methodological issues so much needed in this thesis. Yet I found it difficult at times to isolate important threads and to focus my review since the scope of curriculum reform and evaluation studies was so broad in terms of historical and geographical boundaries in which they occurred. It turned out that these experiences were very valuable to me as I learned how to analyze and synthesize the many pieces of documentary evidence that were relevant.

When I designed my methodology, I was aware of the conflict between the positivist and interpretive paradigms, but I decided to base my methodology on both. This stemmed from my understanding, as informed by literature, that both paradigms could illuminate the study. Evaluation should concern not only outcomes or process but both. Hence, I believed that quantitative and qualitative data complement and offer explanations to each other, thus providing richer information than either one could offer. At the end, I am convinced that my decision was a correct one because both kinds of data if considered alone could not form a picture as complete as it now is.

Apart from the experiences I gained in educational research, I consider my study valuable because it had enabled me to gain many valuable insights into curriculum reform in general, as evaluation basically aims to illuminate how a reform has fulfilled its goals. I could not agree more with Stenhouse's (1975) view of the curriculum:

"[curriculum is] a particular form of specification about the practice of teaching and not a package of materials or a syllabus of ground to be covered. It is a way of translating any educational idea into a hypothesis testable in practice" (p.142).

Applying this argument to the present context of Hong Kong, the new science curriculum is a hypothesis that certain ideas would work to improve students' learning in science in our society. Implementing this curriculum means testing it in the classroom. It must not be taken a priori that a reform should work in Hong Kong simply because it worked elsewhere or if it was invented by countries having a high status in science education. The notion of curriculum implementation as testing out ideas should not only be recognized by curriculum reformers and evaluators but also by teacher educators and teachers. The adoption of a critical stance toward a reform should prevent us from falling into the trap of "self-complacency" as happened in Hong Kong in the past two decades.

Having taken every measure to avoid "self-complacency", perseverance in problem solving is necessary. If teachers rule that a reform is impracticable because of constraints such as large class size or lack of teaching time, they may fall easily into another trap of "mal-adapting" by making only superficial changes as in the case of individual teacher interviewees. To tackle these constraints, curriculum planners, teacher educators and teachers should apply positive problem-solving strategies such as tailoring the content or strengthening teacher training rather than accommodating the problems using mal-adaptive means. Only through these strategies could the "curriculum" hypothesis be put into real tests in the classroom context. If this occurs, curriculum evaluation should perform an even greater service by assessing the worth of the curriculum.

In this thesis, I have learned also the important skills of being an evaluator though some of them appear to be quite trivial at the first glance. When I was collecting data through teacher and student interviews, I found it essential to have the interviewees "warmed up" before starting the formal interview. The context of the interview questions should be explained as far as possible so that the interviewees became more tune in to the interview. This is because being interviewed is not like talking to a friend where people could talk about things in a familiar context. The interviewees have to respond to questions that necessitate organization of ideas, recall of memories, making judgments and expressing them in such a way that is comprehensible to the interviewer. Hence, creating a comfortable environment that facilitates this mental activity is essential. I share Parlett and Hamilton's (1977) view of the evaluators' role:

> *"...research workers in this area need not only technical and intellectual capability, but also interpersonal skills. They seek cooperation but cannot demand it. There may be times when they encounter nervousness and even hostility." (Parlett and Hamilton 1997, p19)*

A well thought out interview protocol and good interviewing techniques should all help to facilitate interviewees in making valid responses.

With the benefit of hindsight, there are corrections I would like to make if I could re-design my interview protocols or questionnaires to elicit more focused responses, say, teachers' specific changes in their practices. I regard not making the best decision at times as a price to pay in my journey to become an effective researcher. I believe I will develop a better foresight in making judgments as I continue that journey.

8.10 Summary

I have described my story of evaluating the new junior secondary science curriculum in Hong Kong. Perhaps, the most important contribution of this thesis to Hong

Kong science education is to give testimony to the worth of a systematic evaluation to a science curriculum reform process. This study informed us that chances are there for the present reform to emerge as a fruitful one in the future. After all, "change is a process, not an event" (Fullan 1982). However with all the constraints likely to persist, a necessary condition for the eventual success of the reform is for curriculum planners, science teachers and teacher educators to join hands and be committed to solving problems in the school and classroom context. Also, the need for continued evaluation of the reform should be fully recognized in order to realize the visions of the reform in the long run.

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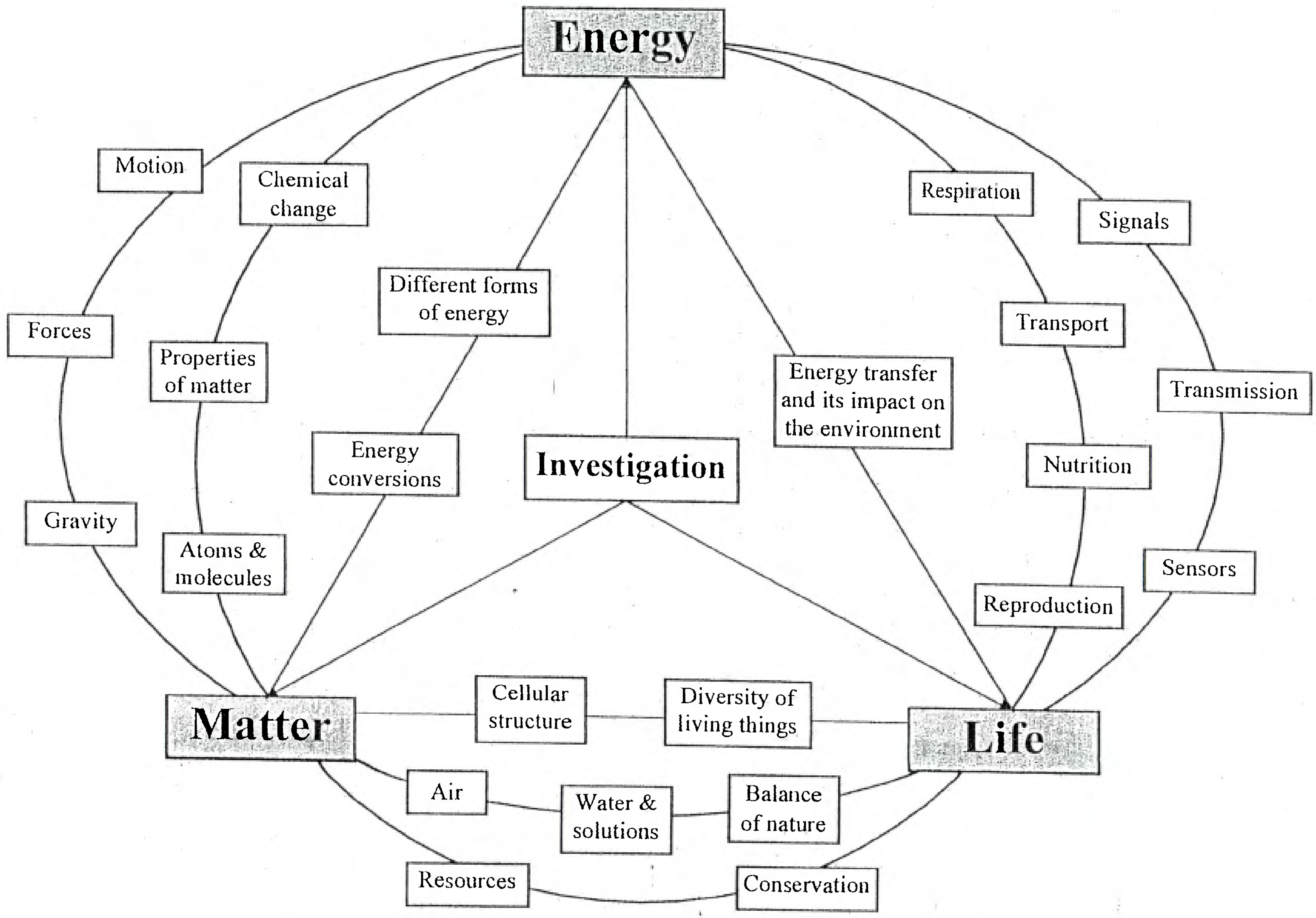
Overview of science curricula at different levels of schooling in Hong Kong

Level of schooling	Science curriculum/subjects
Sixth-forms (Secondary 6-7) Age 17-19	**Physics** **Chemistry** **Biology**
Senior Secondary (Secondary 4-5) Age 15-17	**Physics** **Chemistry** **Biology** **Human Biology** (for Art stream mainly)
Junior Secondary (Secondary 1-3) Age 12-15	**Science** (Previously known as Integrated Science) (Many schools start Physics, Chemistry and Biology at Secondary 3)
Primary (Primary 1-6) Age 6-12	**General Studies** (An integrated curriculum comprising science, health education and social studies)
Pre-primary (K1-3) Age 3-6	No formal science curriculum

Conceptual Framework of the CDC Syllabus for Science (S1-3)



Aims and objectives of the Integrated Science curriculum

AIMS OF SCIENCE EDUCATION

Science education at the secondary level may be seen nowadays as a three stage development, the first of which (Forms I, II and III) is mainly observational in nature, the second (Forms IV and V) is a more interpretative approach with some quantification of concepts, while the third (Forms VI and VII) is a generalization and further refinement of concepts.

It is only during the first three years of secondary education that all pupils in a school study science. It would therefore be logical and desirable to make use of this opportunity to present to the pupils those aspects of science which best contribute to their general education. The broad aims of science education in junior secondary forms are that pupils should acquire:

1. some knowledge of the empirical world around them—
   It is thought desirable to reduce the emphasis on the factual content of the syllabus, to fight shy of any content which seems to have more value to the specialist scientist and to include only those items suited to the stage of development of the children.
2. an introduction to the vocabulary and grammar of science—
   The reading, listening and viewing of everyone is becoming more and more filled with scientific language used to describe the ever-increasing influences of science on our daily lives. This language, in words or otherwise, helps to improve pupils' communication skills.
3. an ability to observe critically—
   It is hoped that teachers will present the situation for learning such that correct answers will not be available to the pupils in advance.
4. an ability to solve problems and think scientifically—
   Through investigative methods the pupils are required to react continuously in a thinking situation.
5. an understanding of the relevance of science to the world beyond school and to the needs of a changing society.
6. an awareness of the culture which is science—
   The corpus of knowledge in science is growing at an explosive rate, and the effect of this growth is to alter not only our physical conditions but also our morals, our ethics, our interests and our whole cultural development.

OBJECTIVES

Having laid out the generalized aims of our science curriculum, it is also desirable to specify the general objectives for the curriculum, upon which the course content and supporting materials should be based.

The general objectives of the course are that pupils should acquire:

A. Knowledge and understanding

1. knowledge of some facts and concepts concerning the environment
2. knowledge of the use of appropriate instruments in scientific experiments
3. an adequate scientific vocabulary
4. an ability to communicate using this vocabulary
5. comprehension of some basic concepts in science so that they can be used in familiar situations
6. ability to select relevant knowledge and apply it to new situations
7. ability to analyse data and draw conclusions
8. ability to think and act creatively in science

B. Attitudes

9. awareness of the inter-relationship of the different disciplines of science
10. awareness of the relationship of science to other aspects of the curriculum
11. awareness of the contribution of science to the economic and social life of the community
12. interest and enjoyment in science
13. an objectivity in observation and in assessing observations

C. Practical skills

14. some simple scientific skills
15. some experimental techniques involving several skills

Interview schedule for curriculum planners

1. What are the factors behind the I.S. curriculum reform? How was the reform initiated?
2. What are the theoretical basis and perceived needs of students or society? Were references drawn from overseas curricula?
3. Were there problems encountered in the developmental process?
4. What do you perceive as the distinctive features of the new curriculum when compared to the old one?
5. Did you try out the new curriculum in some pilot schools?
6. What kinds of training have been or will be provided for schools to facilitate implementation of the new curriculum?
7. What additional resources were or will be provided for schools?
8. What sorts of difficulties would you expect to come up in the first year of implementation?
9. Could you predict the degree of congruence between the intended and implemented curricula?
10. How confident are you that the new curriculum will turn out to be a success?

Letter to the curriculum planner to request for an interview

13 July 2000

Senior Curriculum Development Officer
Curriculum Development Institute

Dear ,

As mentioned to you earlier, I have been conducting a research on the new integrated science curriculum for my doctoral study. The tentative title of my doctoral thesis is "Reform in Hong Kong Junior Secondary Science Curriculum: An evaluation for improvement". The methodology of my research embraces both qualitative and quantitative components. The qualitative part comprises interviews with curriculum planners, secondary school teachers and students, while the quantitative part includes assessment of students' process skills and measurement of students' attitudes toward science and their science self-concepts.

I would be most grateful if I could arrange an interview with you sometime between 20 July and 27 July 2000, or at a date that is most convenient to you. The interview should last no more than an hour. Through the interview, I hope to gain a better insight into the curriculum reform process from your perspective as a curriculum planner. The issues I would like to bring up in the interview include factors behind the I.S. curriculum reform, criteria for selection of content and teaching approaches, major features of the new curriculum, etc.

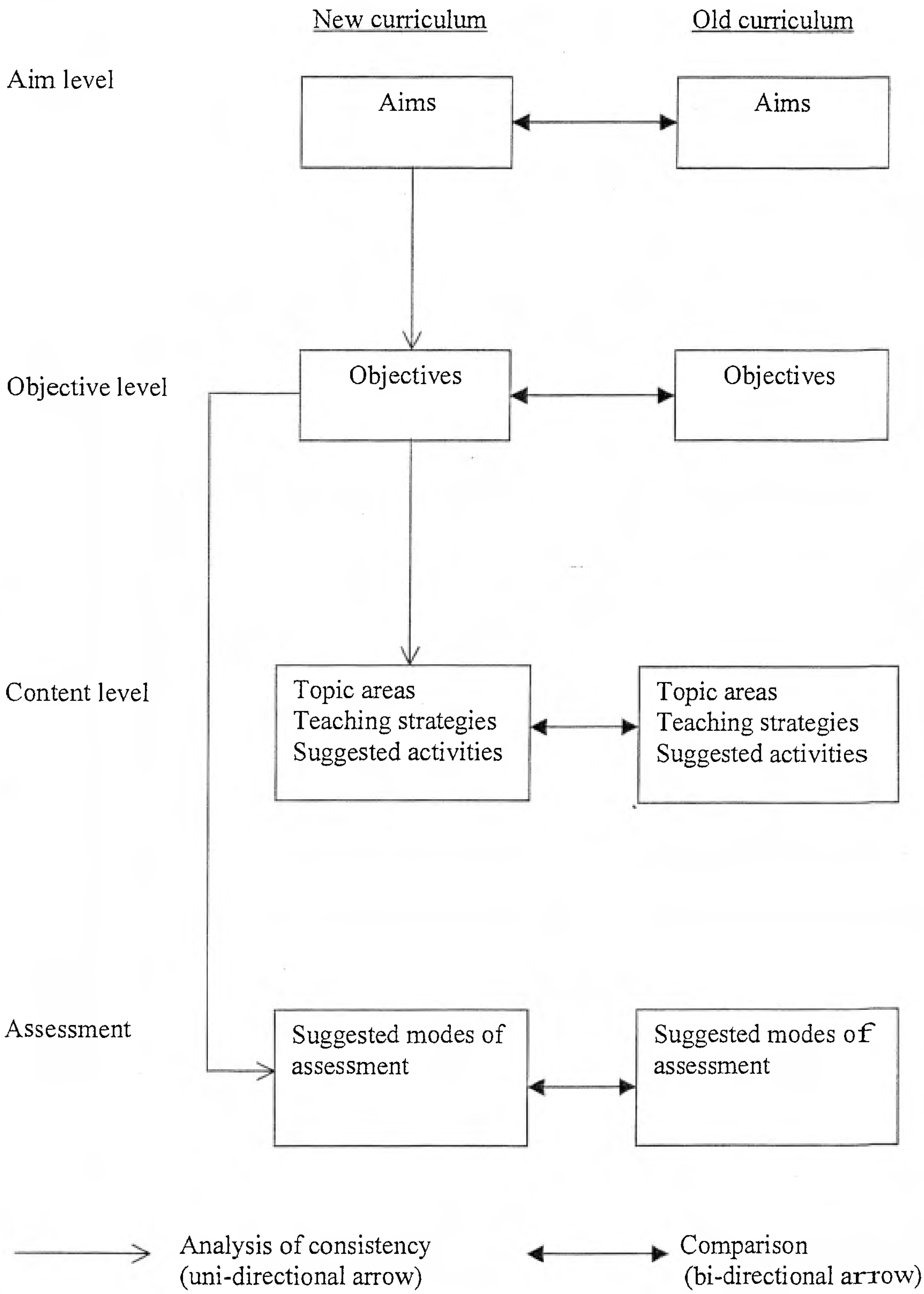
Thank you for your kind support in advance. Please contact me if you have decided on a suitable date and time for the interview, or if you would like me to provide further information. You could reach me at tel. 2948 7658 or through email (email address: yclee@ied.edu.hk).

Yours sincerely,

Lee Yeung Chung
Department of Science

Appendix 4.3

Framework for the documentary analysis of the new curriculum



A sample unit of the new syllabus with a list of suggested activities and the corresponding skills

Unit 2 - Looking at Living Things

Topics	Key points	Content: Core	Content: *Extension*	Suggested activities
2.1 Living things	Characteristics of living things	Living and non-living things Plants and animals		S. Watch video or study pictures showing the characteristics of living things (OB)
2.2 Observing an animal	Observation Habitat	Observing an animal (a pet, a grasshopper, a snail, etc) in terms of its external features, feeding, movement, reaction to stimuli and habitat		S. Observe the external features, feeding, movement, habitat, etc. of an animal (e.g. a pet), discuss their observations (OB, CM) S. Find out how animals react to stimuli (CV)
2.3 Diversity of plant and animal life	Wide variety of living things Variation within the same kind of living things *Bar chart*	Observing the diversity of forms among living things Observing and comparing variation within the same kind of living things, e.g. variation of length of hand spans or size of leaves from the same tree	*Constructing and interpreting bar charts; variation from norm*	S. Collect pictures or photos of living things and present them in a wallchart to show the diversity of forms of living things (CM) S. Find out differences within a species (e.g. height or length of hand span) and present the data in table form (MS, ID) *S. Present the data obtained from the above activity in a bar chart (ID)*
2.4 Sorting things into groups	Keys Classification Animals with and without backbones Flowering and non-flowering plants	Use of simple keys for identification Classifying animals into those with and without backbones Classifying plants into flowering and non-flowering plants	Constructing simple keys for identification *Classifying animals with backbones into fish, amphibians, reptiles, birds & mammals*	S. Identify given specimens or diagrams of animals/plants by means of a given simple key (CS) S. Classify animals into those with or without backbones & plants into flowering and non-flowering plants from given pictures (CS) S. Construct a simple key to identify given living things (CS) *S. Classify animals into fish, amphibians, reptiles, birds or mammals from given pictures of animals with backbones (CS)*
2.5 Endangered species	Endangered species Wild life Effects of man's activities on the environment Conservation	Awareness of the decreasing number and species of plants and animals on earth and the implication for man Inter-dependence of life, e.g. predation Effects of man's activities on wild life Importance of protecting wild life		S. Library search on the issue of endangered species (CM) S. Carry out activities in relation to conservation, e.g. visits to country parks

a. Observing	(OB)
b. Classifying	(CS)
c. Measuring	(MS)
d. Handling apparatus	(EA)
e. Communicating	(CM)
f. Inferring	(IF)
g. Predicting	(PD)
h. Proposing hypotheses	(HP)
i. Interpreting data	(ID)
j. Controlling variables	(CV)

An extract of the new syllabus to show matching of suggested teaching activities with curriculum objectives

Topics	Key points	Content: Core	Content: *Extension*	Suggested activities	Coding
		ozone or ultraviolet light Addition of fluoride to drinking water to prevent tooth decay			
5.3 The water cycle	The water cycle Evaporation Convention current *Rate of evaporation*	The water cycle - formation of clouds (evaporation & condensation), transportation by wind and rain		S. Carry out an experiment to simulate the formation of rain in nature	L1, 2, 3
				S. Watch video on where our drinking water comes from	C1, K3
			Factors affecting the rate of evaporation	*S. Investigate the factors affecting the rate of evaporation [IN]*	S1, 2, 3, 4 L3, 4 C2
5.4 Water conservation and pollution	Conservation of water Water pollution *Need to treat waste water*	Need to conserve water		S. Look at figures of water supply and consumption in HK and discuss ways to conserve water (CM, ID)	C2, 4 A7
		Common causes of water pollution Control of water pollution		S. Watch video on water pollution in HK	K3, C1, A7
				S. Discuss methods of controlling water pollution (CM)	K3, C4, D, A7
			Need to treat waste water before discharging it into the sea *Our responsibility towards minimising water pollution*	S. Suggest ways to reduce wasting water at home and in the community	C4, D, A7
				S. Discuss on the issue of sewage treatment charges (CM)	D, C4, A7

Interview protocols for teachers

1st interview

Perceptions of the new curriculum and science learning

1. How and where did you learn about the new curriculum?
2. Do you think the syllabus/textbook gives you a clear direction of the reform?
3. What do you perceive as the main focus?
4. How does it differ from the old one?
5. What do you think is the most important thing for students to learn in science at this level?

Implemented practices

1. How many laboratory periods are there per week or per cycle?
2. How closely do you stick to the syllabus or textbook?
3. Did you cover the investigations? How do you conduct them in class? How do you think about them?
4. Are the new emphases on assessment reflected in your practices?
5. Did you try out those new teaching approaches suggested in the new syllabus?
6. After going through half of the curriculum, would you consider making any changes to your teaching in the second half?
7. Do you observe any differences in students' attitudes or motivation between the old and the new curriculum?

Factors affecting implementation and perceived changes

1. What factors do you see could affect your teaching of the new curriculum?
2. Have you encountered any difficulties or obstacles so far?
3. What do you think the role of the teacher is in teaching the new curriculum?

Support for teachers

1. Do you think teacher induction is sufficient or helpful? Did you attend any of the training seminars organized by the CDI?
2. Is ongoing support during implementation sufficient?

What other views do you have on the new curriculum?

2nd interview

Personal reflections on the 1st year of implementation of the new curriculum

After teaching for a year, how would you reflect on your experience?
How satisfied are you with the new curriculum? Your teaching? Learning outcomes of your students?
How would you plan for your teaching in the coming year? What changes would you like to make?
Do you see any changes in your teaching environment, e.g. school settings, colleagues support, support from CDI, etc.?

Comments on the findings of the quasi-experimental study

What are your reactions to the results of the study? Does that surprise you?
Could you suggest reasons for the outcomes?
To what extent could you relate this to the curriculum?
What other factors could account for the results?

What other views do you have on the new curriculum?

Teacher questionnaire (trial version)

Teacher survey on the implementation of the new Integrated Science curriculum

This questionnaire survey aims to collect teachers' feedback on the new Integrated Science curriculum with a focus on implementation at Secondary One. This survey constitutes part of a doctoral research for evaluating the new I.S. curriculum. The aim is to provide suggestions for further improvement of the curriculum.

Please tick as appropriate.

Part I

1. Sex : _____ Male _____ Female
2. Years of experience in teaching Integrated Science: ___0-2 ___3-5 ___5-10 ___over 10
3. Are you the I.S. Panel Head of your school? Yes ___ No ___
4. How many classes of Secondary One I.S. are you teaching in this year? ______
5. What is the medium of Instruction of your school? Chinese______ English ______

Part II

6. According to your perception, how large is the difference between the old and new I.S. curriculum with respect to the following areas? (Please tick for each area.)

Areas of the curriculum	Substantially different	With some differences	With little or no differences
Subject content knowledge			
Suggested teaching approaches			
The ways that experiments/investigations are suggested to be conducted			
Suggested methods of assessment			

7. Is the way that you teach under the new curriculum different from the past with respect to the following areas? (Please tick for each area)

Aspects of teaching	Substantially different	With some differences	With little or no differences
The subject knowledge taught			
The teaching approaches you use			
The ways that you teach about practical work			
The ways that you assess your students			

8. Do you agree that the following are the new features of the new curriculum as compared to the old one?

	Agree	Not sure	Disagree
New topic areas/contents are added			
The new topic areas/contents are worthwhile.			
There are more everyday examples showing the relation of science with daily lives.			
A greater variety of teaching methods, including group discussion, debates, projects, role-plays, etc. are included.			
There are more genuine investigative activities			

9. The following investigative activities are suggested for Year One by the Syllabus:

- Design and carry out fair test (Unit 1)
- Design experiments to purify muddy water (Unit 5)
- Perform purification experiments of students' own design(Unit 5)
- Investigate the factors affecting the rate of evaporation(Unit 5)
- Investigating the factors affecting the rate of dissolving (Unit 5)
- Performing a fair test to find the best solvent (Unit 5)

Of the above activities or activities of similar nature included in your textbook, how many have you covered?

____None (Please proceed to Q.11 directly)
____About half of them
____More than half of them

10. In what way did you conduct those activities? (Please tick one ONLY.)

A. I demonstrated most of the activities, but involving the whole class in designing the investigation.	
B. I let students conduct most of the activities in small groups, under my close guidance. E.g. I discussed with them the design and proper procedure of carrying out the investigation before allowing them to proceed on their own.	
C. I let students conduct most of the activities in small groups, providing them with only minimal guidance, e.g. suggesting the types of apparatus available for use.	
D. Others (Please specify):	

11. What are the reason(s) for not covering these activities or covering only part of them? (You may tick more than one.)

A Too time consuming	
B. Lack of adequate equipment and materials in the laboratory	
C. Laboratory periods not adequate to allow sufficient time for investigative work.	
D. Most of these activities suggested by the Syllabus are not included in our textbook.	
E. To avoid discipline problems	
F. I cannot provide sufficient guidance to so many groups at the same time, i.e. the class size is too big.	
G. Most of these investigations are beyond the ability of my pupils.	
H. Others (please specify):	

12. For those who choose (A) or (B) in Q.10, what are your reasons for providing close guidance to students but not giving them a free hand to conduct investigations on their own? (You may tick more than one.)

A. Students can benefit more and learn better in this way.	
B. To avoid discipline problems or confusion likely to be created if students are free to design their investigation.	
C My students lack the ability to conduct investigations on their own.	
D. Can reduce the time required.	
E. We don't have enough apparatus or resources for students to use if they are free to make their own choice.	
F. Others (please specify):	

13. Do you think that investigative activities are worthwhile for learning science?

Very worthwhile	Quite worthwhile	Not worthwhile

14. Do you consider the investigative activities suggested by the Syllabus adequate?

More than adequate	Just right	Not adequate

15. What do you think is the most important benefit of investigative activities for students? (Please tick one ONLY.)

A. There is no benefit.	
B. Developing scientific mind	
C. Enhancing motivation and interest	
D. Enhancing understanding of science knowledge	
E. Fostering scientific attitudes, e.g. open-mindedness, honesty, etc.	
F. Others (please specify):	

16. How confident are you in leading students through investigations to achieve the above aims?

Very confident	Quite confident	Not sure	Quite unconfident	Very unconfident

17. How confident are you in managing group investigations in which students are given minimal guidance on design and procedure beforehand?

Very confident	Quite confident	Not sure	Quite unconfident	Very unconfident

18. How would you rate students' responses to science classes under the new curriculum as compared to students' responses under the old curriculum?

Much better	Somewhat better	More or less the same	Somewhat worse	Much worse

19. Are you satisfied with the new curriculum in relation to the following aspects?(Please tick for each area.)

Areas of the curriculum	Very satisfied	Quite satisfied	Quite unsatisfied	Very unsatisfied
Subject content knowledge				
Suggested teaching approaches				
The ways that experiments/investigations are suggested to be conducted				
Suggested methods of assessment				

20.What are the distinctive features of the new curriculum that you value most, if there are any?

21. When compared to the old curriculum, do you consider that the new curriculum is more able or less able to achieve the following aims?

Aims	Much more able	More able	More or less the same	Less able	Much less able	Difficult to tell
Acquire the basic scientific knowledge and concepts for living in and contributing to a scientific and technological world						
Develop the ability to enquire and to solve problems						
Be acquainted with the language of science and be equipped with the skills in communicating ideas in science related contexts						
Develop curiosity and interest in science						
Recognize the usefulness and limitations of science and the interactions between science, technology and society and develop an attitude of responsible citizenship						
Be able to appreciate and understand the evolutionary nature of scientific knowledge						

22. Are you convinced that the new curriculum is an improvement over the old curriculum?

Totally convinced	Quite convinced	Not sure	Quite unconvinced	Totally unconvinced

23. Do you think that more training is needed by teachers to implement the new curriculum?
___Yes __No

24. If yes, in what areas is training needed? (You may tick more than one.)

A. Familiarization with new content/topics	
B. Familiarization with the process of scientific investigation	
C. Familiarization with the skills in leading students through scientific investigative activities.	
D. Familiarization with non-conventional teaching strategies/methods for teaching science, e.g. group discussion, debates, role-plays, projects, etc.	
E. Familiarization with the methods and skills in assessing students' process skills	
F. Others (please specify):	

25. Did you attend any of the seminars or workshops conducted by the CDI to familiarize teachers with the new curriculum?
___All or most of them ___Some ___None

26. Are there other resources necessary for the effective implementation of the new curriculum?

27. What other recommendations would you like to make to improve science curriculum at the junior secondary level?

End of questionnaire

Thank you very much

Teacher questionnaire (final version)

Hong Kong Institute of Education
Teacher survey on the implementation of the new Integrated Science curriculum

This questionnaire survey aims to collect teachers' feedback on the new Integrated Science curriculum with a focus on implementation at **Secondary One**. This survey constitutes part of a research conducted by the Institute for evaluating the new I.S. curriculum. Your contribution to this study is very much appreciated. The responses given will be kept confidential and no respondent will be quoted by name or institution in any publication arising from the work.

Please use the returned envelope for returning the completed questionnaire. Thank you.

Lee Yeung Chung
Lecturer, Department of Science
Hong Kong Institute of Education

Please tick as appropriate.

Part I

1. Sex : _____ Male _____ Female

2. Years of experience in teaching Integrated Science:

   ___Teaching I.S. for the 1st year ___2-5 ___6-10 __ 11 or more

3. Please state your job title? ___I.S. Panel Head ___I.S. teacher

4. How many classes of Secondary One I.S. are you teaching in this year? ______

5. What is the medium of instruction of your school? ______Chinese ______English

Part II

6. From what source material is your understanding of the new I.S. curriculum derived? (If there is more than one source, please rank them in order 1,2,3 etc. to show their importance to you, "1" being the most important.)

Source	Ranking
a) Syllabus and curriculum guide	
b) Textbook	
c) Teacher seminars or workshops organized by the CDI	
d) I.S. Panel meetings of your school	
e) Others (Please specify):	

7. According to your perception, how different is the new I.S. curriculum from the old with respect to the following areas? (Please tick for each area. **This question is not applicable to teachers teaching I.S. for the first time.**)

Area of the curriculum	Very different	Different in only some areas	Little or no differences
a) Subject content knowledge			
b) Suggested teaching approaches			
c) The ways that experiments/investigations are suggested to be conducted			
d) Suggested methods of assessment			

8. Is the way that you teach under the new curriculum different from the past with respect to the following areas? (Please tick for each aspect. **This question is not applicable to teachers teaching I.S. for the first time.**)

Aspects of teaching	Very different	Different in only some areas	Little or no differences
a) The subject knowledge taught			
b) The teaching approaches you use			
c) The ways that you teach about practical work			
d) The ways that you assess your students			

9. To what extent do you agree that the following are the new features of the new curriculum compared with the old one? (Please tick for each feature. **This question is not applicable to teachers teaching I.S. for the first time.**)

Features	Agree strongly	Agree	Disagree	Disagree strongly
a) The new topic areas/contents are worthwhile.				
b) There are more everyday examples showing the relation of science with daily lives.				
c) More emphasis is placed on the nature of science and the evolution of scientific knowledge.				
d) A greater variety of teaching methods, including group discussion, information search, etc. are suggested.				
e) There are more open-ended investigative activities.				
f) Encouraging teachers to adopt a more flexible approach toward teaching rather than following rigid procedures or guidelines				
g) Better quality of textbook				
h) Others (Please specify):				

10. The following investigative activities are suggested for Year One by the Syllabus:
- Design and carry out fair test (Unit 1)
- Design experiments to purify muddy water (Unit 5)
- Perform purification experiments of students' own design (Unit 5)
- Investigate the factors affecting the rate of evaporation(Unit 5)
- Investigating the factors affecting the rate of dissolving (Unit 5)
- Performing a fair test to find the best solvent (Unit 5)

Of the above activities or activities of similar nature included in your textbook, how many have you covered?

____None (Go on to Q.11)
____Less half (Go on to Q.11)
____About half (Go on to Q.11)
____More than half (Go on to Q.11)
____All or almost all (Go to Q.12)

11. What is/are the reason(s) for not covering these activities or covering only part of them? (If you have more than one reason, please rank them in order 1,2,3, etc. to show their degree of importance, "1" being the most important.)

Reasons	Ranking
a) Not meaningful	
b) Too time consuming	
c) Lack of adequate equipment and materials in the laboratory	
d) Laboratory periods not adequate to allow sufficient time for investigative work.	
e) Most of these activities suggested by the Syllabus are not included in our textbook.	
f) To avoid discipline problems	
g) I cannot provide sufficient guidance to so many groups at the same time, i.e. the class size is too big.	
h) Most of these investigations are beyond the ability of my pupils.	
i) Students' language ability is inadequate.	
j) Others (please specify):	

12. Which strategy most closely represents the one you used most often in teaching investigative activities? (Please tick ONE only.)

a) I demonstrated most of the activities, but involving the whole class in designing the investigation. (Go on to Q.13)	
b) I let students conduct most of the activities in small groups, under my close guidance. E.g. I discussed with them the design and proper procedure of carrying out the investigation before allowing them to proceed on their own. (Go on to Q.13)	
c) I let students conduct most of the activities in small groups, providing them with only minimal guidance, e.g. suggesting the types of apparatus available for use.(Go to Q.14)	
d) Others (Please specify):	

13. What is/are your reason(s) for providing close guidance to students but not giving them a free hand to conduct investigations on their own? (If you have more than one reason, please rank them in order 1,2,3, etc. to show their degree of importance, "1" being the most important.)

Reasons	Ranking
a) Students can benefit more and learn better in this way.	
b) To avoid discipline problems or confusion likely to be created if students are free to design their investigation.	
c) My students lack the ability to conduct investigations on their own.	
d) Can reduce the time required.	
e) We don't have enough apparatus or resources for students to use if they are free to make their own choice.	
f) Students' language ability is inadequate.	
g) Others (please specify):	

14. What do you think is/are the benefit(s) of investigative activities for students? (If there is more than one benefit, please rank them in order 1,2,3, etc. to show their degree of importance, "1" being the most important.)

Benefits	Ranking
a) There is no benefit.	
b) Developing scientific mind	
c) Enhancing motivation and interest	
d) Enhancing understanding of science knowledge	
e) Fostering scientific attitudes, e.g. open-mindedness, honesty, etc.	
f) Building up self-confidence and assurance of one's ability	
g) Others (please specify):	

15. How confident are you in leading students through investigations to achieve the above aims?

Very confident	Quite confident	Quite unconfident	Very unconfident

16. In your view has students' attitudes and/or motivation for science changed under the new curriculum? (**This question is not applicable to teachers teaching I.S. for the first time.**)

Much more positive	Positive	Unchanged	More negative	Much more negative

Please give reasons:________________________________

17. Are you satisfied with the new curriculum in relation to the following areas? (Please tick for each area and give REASONS for your answers.)

Areas of the curriculum	Very satisfied	Quite satisfied	Quite unsatisfied	Very unsatisfied	**Please give REASONS for being satisfied or unsatisfied**
a) Subject content knowledge					
b) Suggested teaching approaches					
c) The ways that experiments/investigations are suggested to be conducted					
d) Suggested methods of assessment					

18. What distinctive features of the new curriculum do you value most?

____

19. In your view, what are the obstacles to the effective implementation of the new curriculum?

____

20. When compared to the old curriculum, do you agree that the new curriculum is more able to achieve the following aims? (Please tick for each aim. **This question is not applicable to teachers teaching I.S. for the first time.)**

Aims	Highly agree	Agree	Not sure	Disagree	Highly disagree
a) Acquire the basic scientific knowledge and concepts for living in and contributing to a scientific and technological world					
b) Develop the ability to enquire and to solve problems					
c) Be acquainted with the language of science and be equipped with the skills in communicating ideas in science related contexts					
d) Develop curiosity and interest in science					
e) Recognize the usefulness and limitations of science and the interactions between science, technology and society.					
f) Be able to make objective judgements or value judgements concerning science issues that have an impact on society based on knowledge and data.					
g) Be able to appreciate and understand the evolutionary nature of scientific knowledge					

21. Are you convinced that the new curriculum is an improvement over the old curriculum? (**This question is not applicable to teachers teaching I.S. for the first time.**)

Totally convinced	Convinced	Not sure	Unconvinced	Totally unconvinced

Please explain:_______________

22. Do you think that more training is needed by teachers to implement the new curriculum?
___Yes (Go on to 23)
___No (Go to 24)

23. If yes, in what areas is training needed? (Please rank your answers in order 1,2,3,etc. to show their importance, "1" being the most important.)

Areas	Ranking
a) Familiarization with new content/topics	
b) Familiarization with the process of scientific investigation	
c) Familiarization with the skills in leading students through scientific investigative activities.	
d) Familiarization with non-conventional teaching strategies/methods for teaching science, e.g. group discussion, debates, role-plays, projects, etc.	
e) Familiarization with the methods and skills in assessing students' process skills	
f) Others (please specify):	

24. Did you attend any of the seminars or workshops conducted by the CDI to familiarize teachers with the new curriculum?
___None (Go on to Q.25)
___Some (Go to Q.26)
___Most or all of them (Go to Q.26)

25. What are your reasons for not attending those seminars? (If you have more than one reason, please rank them in order 1,2,3, etc. to show their degree of importance, "1" being the most important.)

Reasons	Ranking
a) I wasn't notified.	
b) I am too busy with my teaching.	
c) The school was represented by other colleagues, e.g. panel head.	
d) Other reasons (Please specify)	

(Go to Q.27)

26. Please give an indication of the value of these seminars for your preparation for teaching the new curriculum.

Extremely useful — Totally not useful

5	4	3	2	1

27. Do you think that you are adequately prepared for implementing the new curriculum?
___Yes ___No

Please explain:____

28. Are there other resources necessary for the effective implementation of the new curriculum?

____Yes (Rosources required:____)
____No

29. What other recommendations would you like to make to improve science curriculum at the junior secondary level?

____

End of questionnaire
Thank you very much

Teacher questionnaire (final version)(Chinese)

香港教育學院

綜合科學(I.S.)新課程教師意見調查

各位中一科學老師：

本問卷旨在瞭解中一科學教師對本學年首次實施的 I.S.課程的意見。這次問卷調查是一項對新 I.S.課程的檢討研究的一部份。你的參與對是項研究起著很重要作用。希望你能撥出少許時間填寫這份問卷，並使用回郵信封寄回。個別老師及學校所提供的資料將絕對保密。

最後，再一次多謝閣下撥出寶貴時間完成這份問卷。

香港教育學院科學系講師 李揚津

甲部：請在適當空格內加「✓」號。

1. 性別： □男 □女
2. 你任教綜合科學科(I.S.)的經驗： □第一年任教 □2-5 年 □6-10 年 □11 年或以上
3. 你在學校 I.S 科擔任的職位： □科主任 □教師
4. 你今年任教中一科學的班數： □1 □2 □3 □4 □5
5. 學校所採用的教學語言： □中文 □英文

乙部： 請在適當空格內加「✓」號。

6. 你對新 I.S.課程的了解主要是從何處獲得？ (若答案不只一個，請按其重要性以 1、2、3…表示。1 爲最主要的，如此類推。)

資料來源	重要性
a) 課程綱要及課程指引	
b) 教科書	
c) 課程發展處所舉辦的教師研討會或工作坊	
d) 學校的科務會議	
e) 其他 (請說明)：	

7. 就下列四個課程範疇，你認爲科學科的新課程與舊課程有多大分別？(請就每個範疇在適當地方加「✓」號。此題不適用於首次任教 I.S.科者。)

課程範疇	有很大分別	有某些分別	無分別或只有少許分別
a) 課題內容			
b) 教學策略及方法			
c) 進行實驗/探究的方法			
d) 評估學習的方法			

8. 就以下四個項目，指出新課程實施後，你在施教上與過去有何分別？(請就每個項目在適當地方加「✓」號。此題不適用於首次任教 I.S.科者。)

項目	有很大分別	有某些分別	無分別或只有少許分別
a) 你所施教的課題及內容			
b) 你所採用的教學策略及方法			
c) 你帶領學生進行實驗/探究的方法			
d) 你評估學生學習的方法			

1

9. 與舊課程相比，你是否同意以下各項是新課程的特點？(請就每個項目在適當地方加「✓」號。此題不適用於首次任教 I.S.科者。)

項目	非常同意	同意	不同意	非常不同意
a) 課題及內容更值得學生學習				
b) 內容較生活化，能反映科學與生活的關係				
c) 較著重描述科學的本質及科學知識的演進				
d) 包含多元化的教學策略及方法，例如：小組討論、資料搜集等				
e) 包含較多開放式的探究活動				
f) 鼓勵老師更有彈性及更靈活地進行教學，而不只是按既定步驟進行				
g) 教科書的質素有所提升				
h) 其他(請說明)：				

10. 以下是新課程綱要建議中一級進行的探究活動：

單元一	單元五
● 設計和進行公平測試	● 設計實驗將污水淨化 ● 進行學生自己設計的污水淨化實驗 ● 探究影響蒸發速率的因素 ● 探究影響溶解速率的因素 ● 進行公平測試，找出清除衣服上油漬的最佳溶劑

在以上各項活動或教科書所建議的類似探究活動中，你完成了多少？

沒有 (繼續第 11 題)	少於一半 (繼續第 11 題)	約一半 (繼續第 11 題)	多於一半 (繼續第 11 題)	全部或差不多全部 (跳至第 12 題)

11. 如你沒有進行部份或全部探究活動，原因是甚麼？ (若原因不只一個，請按其重要性以 1、2、3…表示。1 爲最重要的，如此類推。)

原因	重要性
a) 這些活動沒有多大意義。	
b) 這些活動需時太長。	
c) 實驗室未具備足夠器材。	
d) 實驗課的節數不足。	
e) 我校使用的教科書很少這方面的活動。	
f) 避免出現秩序問題。	
g) 學生人數太多，使我無法給予每組足夠的指導。	
h) 探究活動超越了學生的能力範圍。	
i) 學生的語文能力不足。	
j) 其他原因(請說明)：	

2

12. 以下哪一項最能夠形容你帶領學生進行探究活動的方式？（只✓一項）

a) 由教師示範，但進行時會與學生一同討論探究方法或要求他們提供意念。(繼續第 13 題)	
b) 由學生分組進行，但教師事先會和學生詳細討論探究方法或給予指導。(繼續第 13 題)	
c) 由小組自行決定探究方法，教師只提供少量輔導，例如只提供可使用的器材。（跳至第 14 題)	
d) 其他進行方法(請說明)：	

13. 進行探究前，你會先和學生詳細討論探究的方法，而不讓學生自行決定如何探究，原因是甚麼？（若原因不只一個，請按其重要性以 1、2、3…表示。1 爲最重要的，如此類推。）

原因	重要性
a) 在老師的指導下進行探究活動，學生的得益會更多。	
b) 如讓學生自行決定探究方法，容易出現混亂及秩序問題。	
c) 我的學生尙未具備自行探究的能力。	
d) 給予較詳細指引可以節省時間。	
e) 我校沒有足夠器材讓學生自行探究。	
f) 學生的語文能力不足。	
g) 其他原因(請說明)：	

14. 你認爲探究活動能爲學生帶來的益處是甚麼？(若益處不只一個，請按其重要性以 1、2、3…表示。1 爲最重要的，如此類推。)

益處	重要性
a) 沒有益處	
b) 培養科學頭腦	
c) 提高學習科學的動機及興趣	
d) 增進對科學知識的瞭解	
e) 培養科學態度，如客觀、尋根究柢的精神	
f) 幫助學生建立自信心及肯定自己的能力	
g) 其他益處(請說明)：	

15. 你是否有信心帶領學生進行探究活動，以達致上述目標？

很有信心	頗有信心	稍欠信心	很欠信心

16. 與舊課程相比，你認爲學生在新課程下，對科學的態度及學習科學的動機是否有所改變？(此題不適用於首次任教 I.S.科者。)

較以前好得多	較以前好	沒有分別	較以前差	較以前差很多

請指出原因：________________________________

____

17. 就以下各項，你對新課程是否感到滿意？(請就每項在適當地方加✓號，並指出原因。)

	很滿意	頗滿意	頗不滿意	很不滿意	請寫出滿意或不滿意的原因
a) 課題內容					
b) 教學策略及方法					
c) 進行實驗/探究的方法					
d) 學習的評估方法					

18. 你認爲新課程最有價值的東西是甚麼？

____

____

19 你認爲哪些不利因素會阻礙新課程的成功推行？

____

____

20. 你是否同意新課程比舊課程較容易達到下列目標？(請就每項目標在適當地方加「✓」號。此題不適用於首次任教 I.S.科者。)

目標	很同意	頗同意	不肯定	頗不同意	很不同意
a) 獲得基本的科學知識及概念，以便在這廣受科學和科技影響的世界中生活，並作出貢獻。					
b) 培養科學方法和解決問題的技能					
c) 熟習運用科學語言，並掌握相關的傳意技能，如闡釋資料及提出証據					
d) 培養對科學的好奇心及興趣。					
e) 瞭解科學的實用性和局限性，認識科學、科技及社會的相互影響					
f) 能根據數據及資料，就足以影響社會的科學問題作客觀判斷或價值取捨					
g) 能夠理解和接受科學知識不斷演進的特質。					

21. 與舊課程相比，你是否相信新課程是一項進步？

絕對相信	頗爲相信	不肯定	頗不相信	絕不相信

請解釋原因：________________________________

22. 你認爲教師是否需要接受更多培訓，以便推行新課程？

□是 (繼續第 23 題)　　□否 (跳至第 24 題)

23. 如是，教師培訓應讓老師熟習哪方面？(若答案不只一個，請按其重要性以 1、2、3...表示。1 爲最重要的，如此類推。)

項目	重要性
a) 新課題的內容	
b) 科學探究的方法	
c) 帶領學生進行科學探究所須的技巧	
d) 使用非傳統的教學方法教授科學 (如小組討論、專題探討、辯論等) 教授部份內容	
e) 評核學生探究及實驗技能的方法	
f) 其他(請說明)：	

24. 你曾否參加課程發展處就新課程所舉辦的教師研討會或工作坊？

完全沒有參加 (繼續第 25 題)	參加了一部分 (跳至第 26 題)	參加了全部或大部份 (跳至第 26 題)

25. 如你完全沒有參加，主要原因是甚麼？(若原因不只一個，請按其重要性以 1、2、3...表示。1 爲最重要的，如此類推。)

原因	重要性
a) 沒有接獲通知。	
b) 工作太忙，無暇出席。	
c) 學校已有代表出席，如科主任。	
d) 其他原因(請說明)：	

(請跳至第 27 題。)

26. 你認爲這些研討會或工作坊對你準備教授新課程是否有幫助？

「5」代表非常有幫助　　「1」代表完全無幫助

5	4	3	2	1

27. 你認爲自己對推行新課程的準備是否充足？ □是 □否

請解釋：______________________________

28. 你認爲要有效推行新課程，是否還需要其他方面的資源？如是，請說明。

□是 (所須資源：______________________________)

□否

29. 你對改善初中的科學課程還有甚麼建議？______________________________

____

十分感謝你回答及寄回這份問卷！

Attitudinal scales (trial version)(English & Chinese)

Hong Kong Institute of Education
Department of Science

This questionnaire aims to find out the attitudes of Secondary 1 students toward science and science curriculum, and their science self-concept. It constitutes part of a research on junior secondary science education. The responses given will be kept confidential.

Please circle a number against each statement to represent your extent of agreement to that statement. Each number represents different levels of agreement as explained below:-

Strongly agree	Agree	Not sure	Disagree	Strongly disagree
5	4	3	2	1

Class no. ___________ Sex: ___________ Age: _________

		Strongly agree				Strongly disagree
1	Science is fun.	5	4	3	2	1
2	I think scientists are neat people.	5	4	3	2	1
3	I enjoy science courses.	5	4	3	2	1
4	Science is boring.	5	4	3	2	1
5	Everyone should learn about science.	5	4	3	2	1
6	I have good feelings toward science.	5	4	3	2	1
7	I would enjoy being a scientist.	5	4	3	2	1
8	Learning science helps me to cope with the world.	5	4	3	2	1
9	Science is too technical.	5	4	3	2	1
10	We do a lot of fun activities in science class.	5	4	3	2	1
11	We learn about important things in science class.	5	4	3	2	1
12	We cover interesting topics in science class.	5	4	3	2	1
13	I like our science textbook.	5	4	3	2	1
14	I have always done well in science.	5	4	3	2	1
15	Compared to others my age I am good at science.	5	4	3	2	1
16	I get good marks in science.	5	4	3	2	1
17	Work in science classes is easy for me.	5	4	3	2	1
18	I am hopeless when it comes to science.	5	4	3	2	1
19	I learn things quickly in science.	5	4	3	2	1

香港教育學院科學系

本問卷的目的在了解中一學生對科學的態度和自我觀，以作爲研究初中科學教育的參考。問卷的內容將會保密。

請根據以下準則，在每題圈出一個數字，以表示你對該問題的同意程度。

極同意	同意	不肯定	不同意	極不同意
5	4	3	2	1

學號：__________　　性別：________　　年齡：__________

		極同意				極不同意
1	科學十分有趣。	5	4	3	2	1
2	我覺得科學家做事小心及有效率。	5	4	3	2	1
3	學習科學爲我帶來樂趣。	5	4	3	2	1
4	我覺得科學十分沉悶。	5	4	3	2	1
5	每個人都應該學習科學。	5	4	3	2	1
6	我對科學有好感。	5	4	3	2	1
7	我喜愛當科學家。	5	4	3	2	1
8	學習科學可以幫助我應付周圍的世界。	5	4	3	2	1
9	科學過於專門。	5	4	3	2	1
10	在科學堂上，我們學習到有趣的課題。	5	4	3	2	1
11	在科學堂上，我們學習到重要的東西。	5	4	3	2	1
12	在科學堂上，我們做很多有趣的活動。	5	4	3	2	1
13	我喜歡我們所用的科學教科書。	5	4	3	2	1

請轉後頁 • • •

		極同意				極不同意
14	我向來在科學科都有良好表現。	5	4	3	2	1
15	與其他相同年齡的同學比較，我在科學科的表現良好。	5	4	3	2	1
16	我在科學科得到良好成績。	5	4	3	2	1
17	科學堂上所進行的活動對我來說可算容易。	5	4	3	2	1
18	我沒有能力學好科學。	5	4	3	2	1
19	我很快便能學到科學科的內容。	5	4	3	2	1

Appendix 4.11

Attitudinal scales (final version) (English & Chinese)

Hong Kong Institute of Education
Department of Science

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Strongly agree	Agree	Not sure	Disagree	Strongly disagree
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Class no. ___________ Sex: ___________ Age: _________

		Strongly agree				Strongly disagree
1	Science is fun.	5	4	3	2	1
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4	Science is boring.	5	4	3	2	1
5	Everyone should learn about science.	5	4	3	2	1
6	I have good feelings toward science.	5	4	3	2	1
7	I would enjoy being a scientist.	5	4	3	2	1
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9	We do a lot of fun activities in science class.	5	4	3	2	1
10	We learn about important things in science class.	5	4	3	2	1
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16	Work in science classes is easy for me.	5	4	3	2	1
17	I am hopeless when it comes to science.	5	4	3	2	1
18	I learn things quickly in science.	5	4	3	2	1

本問卷的目的在了解中一學生對科學的態度和自我觀，以作爲研究初中科學教育的參考。問卷的內容將會保密。

請根據以下準則，在每題圈出一個數字，以表示你對該問題的同意程度。

極同意	同意	不肯定	不同意	極不同意
5	4	3	2	1

學號：________　　性別：________　　年齡：________

		極同意				極不同意
1	科學十分有趣。	5	4	3	2	1
2	我覺得科學家做事小心及有效率。	5	4	3	2	1
3	學習科學爲我帶來樂趣。	5	4	3	2	1
4	我覺得科學十分沉悶。	5	4	3	2	1
5	每個人都應該學習科學。	5	4	3	2	1
6	我對科學有好感。	5	4	3	2	1
7	我喜愛當科學家。	5	4	3	2	1
8	學習科學可以幫助我應付周圍的世界。	5	4	3	2	1
9	在科學堂上，我們學習到有趣的課題。	5	4	3	2	1
10	在科學堂上，我們學習到重要的東西。	5	4	3	2	1
11	在科學堂上，我們做很多有趣的活動。	5	4	3	2	1
12	我喜歡我們所用的科學教科書。	5	4	3	2	1

請轉後頁 • • •

		極同意				極不同意
13	我向來在科學科都有良好表現。	5	4	3	2	1
14	與其他相同年齡的同學比較，我在科學科的表現良好。	5	4	3	2	1
15	我在科學科得到良好成績。	5	4	3	2	1
16	科學堂上所進行的活動對我來說可算容易。	5	4	3	2	1
17	我沒有能力學好科學。	5	4	3	2	1
18	我很快便能學到科學科的內容。	5	4	3	2	1

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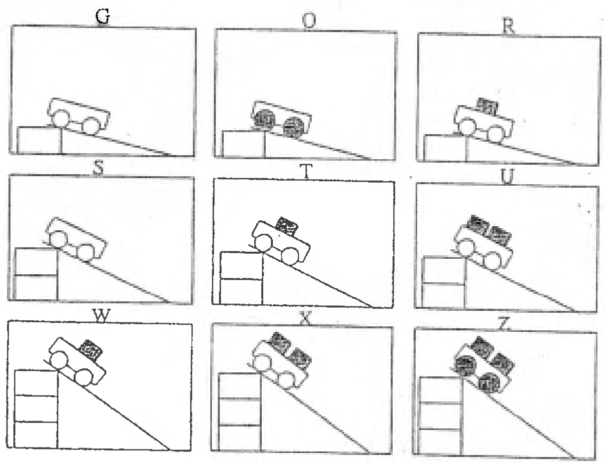
Paper-and-pencil test (Chinese version)

本卷分甲、乙兩部份。甲部爲多項選擇題，乙部爲問答題。

甲部：多項選擇題

細心閱讀每條題目，並圈出你認爲是最佳的答案。

1. 下圖顯示一名學生利用兩架輪子大小不同的小車所進行的試驗。小車是從不同的高度滑下。車上所承載的每件重物的重量相同。



如果該名學生要測試以下構想：小車愈重，到達斜面底部時的速率就愈快。他應該比較哪三個試驗？

A. G, T, and X

B. O, T, and Z

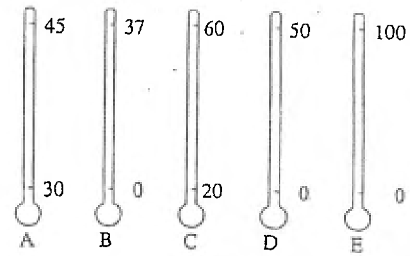
C. R, U, and Z

D. S, T, and U

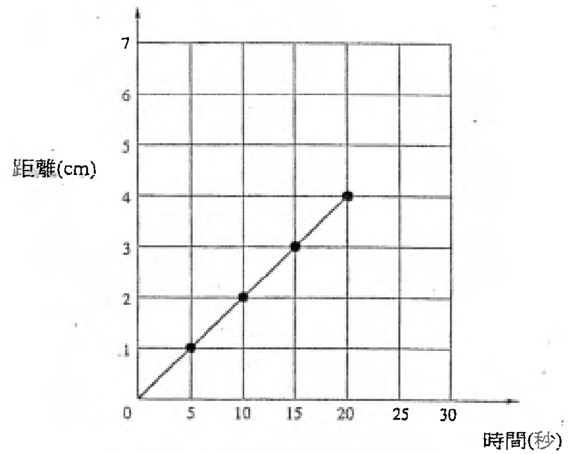
E. S, W, and X

2. 下圖顯示五種不同的攝氏溫度計。一般病者的體溫是在 36°C 至 42°C 之間。哪一種最適合用來量度體溫？

A. 溫度計 A
B. 溫度計 B
C. 溫度計 C
D. 溫度計 D
E. 溫度計 E



3. 下圖顯示一隻螞蟻沿著一條直線行走的進度。



若螞蟻保持速率不變，30 秒後螞蟻和起點相距多少？

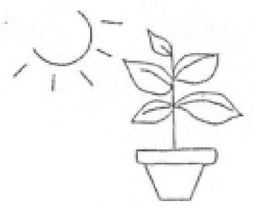
A. 5 cm

B. 6 cm

C. 20 cm

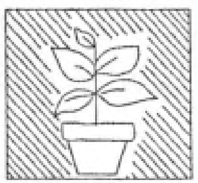
D. 30 cm

4. 一名女童認爲植物需要從泥土中吸收礦物質才能正常地生長。她把一棵植物放在陽光下（如圖所示）。

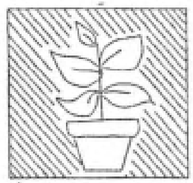


要驗證她的構想是否正確，她還需要另一棵植物。她還需要使用以下哪一棵植物？

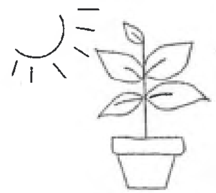
A. 黑暗的箱子內



B. 黑暗的箱子內

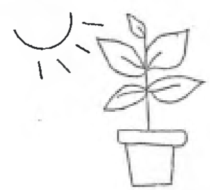


C. 陽光

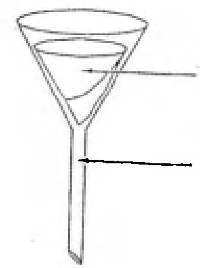


D. 陽光

E. 陽光



5. 使用以下的儀器進行過濾可以把哪兩種物質分離？



A. 糖和水的溶液
B. 鹽和水的溶液
C. 水和酒精的混合物
D. 泥和水的混合物
E. 沙和木糠的混合物

乙部：問答題

細心閱讀以下問題，並盡力回答。

1. 空氣是無色、無臭和無味的。請描述一種方法以顯示空氣的存在。

2. 如果你要探究人的心跳速率是如何受身體活動的變化所影響，你會使用甚麼用具和進行哪些步驟？

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Solutions (Chinese version)

溶液

你需要的工具：

熱水與冷水
幾個燒杯
藥片
攪拌棒
具有秒針的錶
溫度計
三十厘米直尺

小心閱讀以下指示

你的任務： 試找出不同溫度對藥片溶解速度的影響

你要完成的工作：

- 設計一個實驗來找出不同溫度對藥片溶解速度的影響

1. 先寫出你的實驗步驟，包括
   - 你需要量度什麼
   - 要量度多少次
   - 如何用表格列出所量度的結果

2. 進行你設計的實驗，用表格將結果列出

3. 根據你的實驗結果，不同的溫度對藥片溶解的速度有什麼影響？

4. 試解釋爲什麼不同的溫度會有這樣的效果。

5. 如你再做此項實驗，你會作出什麼修改？試列出所作的修改及加以解釋。如不需修改，則寫上「不變」。

將燒杯的水倒入污水盆，然後抹乾燒杯，把所有工具放回原處

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Elastic band (Chinese version)

橡皮圈

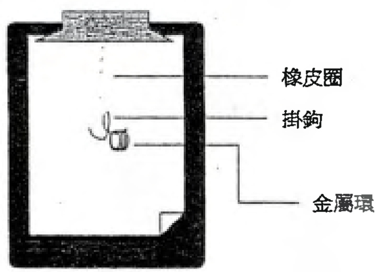
你需要的用具：

- 寫字板及橡皮圈
- 扣在橡皮圈末端的大掛鉤
- 金屬環(掛在大掛鉤上)
- 30cm長直尺
- 數張白紙
- 兩張格仔紙
- 海棉墊

仔細閱讀以下各項指示。

你的任務：

找出把越來越多金屬環掛於橡皮圈時，橡皮圈的長度會如何變化。



你要完成的工作：

- 把金屬環一個一個地掛在掛鉤上。
- 每加一環，須量度橡皮圈的長度。
- 把數據記錄在表格內。

1. 把你的數據記錄在表格內。記著爲每直行加上標題。

2. 在格仔紙上，把你的結果用圖表或棒型圖的方式表示出來。

利用你的表格，圖表或棒型圖，回答第三至第六條問題。

3. 若掛鉤上已掛著兩個金屬環，如再加上三個金屬環，橡皮圈的長度會增加多少?

   橡皮圈的長度會增加__________cm.

4. 描述當你把金屬環一個一個加在掛鉤上時，橡皮圈的長度有什麼改變？

轉下頁

5. 當所有的金屬環已掛上後,此時若再加兩個環,橡皮圈的長度會是多少?

我估計像皮圈的總長度是________________cm.

6. 你以上的估計有何根據?

把所有工具放回原處,以方便其他人使用此工作站。

Appendix 4.18

Interview protocol for students

1. What struck you most while performing the tasks?
2. What are your feelings about it, say Solutions? Interesting, boring?
3. Are they difficult? Which parts? Why? Which task is more interesting, more difficult?
4. Are these tasks familiar to you? Have you done similar sorts in your class? How do these compare with what you do in class?
5. How do you describe the way you perform experiments in class?
6. Would you like to change them to something similar to these tasks? Why or why not ?
7. What are your views about the curriculum that you are studying?
8. What changes would you most like to see to the curriculum?

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