The Effects of the Medium of Instruction on Science Learning of Hong Kong Secondary Students

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ABSTRACT

Starting from 1998, a new language policy on the medium of instruction for secondary schools is implemented in Hong Kong. The policy stipulates that only 25% of secondary schools, which take in students with better academic and language abilities, are allowed to use English, the students' second language, as the medium of instruction, and the others have to use Chinese, the native language, for instruction. The present research project is a longitudinal study that aims to explore the effects of this language policy on the science learning of the English-medium and Chinese-medium students in the first three years of secondary schooling. The learning outcomes of the two streams of students were assessed by science achievement tests and a questionnaire on students' self-concept in science. The results obtained show that the English-medium students were disadvantaged in science learning, as they had relatively lower achievement scores and lower self-concept in science than those who learned through Chinese. Based on the analysis of students' performance on the test items, their perception of classroom climate in science lessons and classroom observations, the negative effects of learning science through English can be related to the limited English proficiency of the immersion students and inadequate repertoire of instructional strategies used by the science teachers. These negative effects, however, tended to become reduced with increase in time of immersion, probably because the English-medium students had become more proficient in English language skills and more confident in learning through English. Recommendation on the implementation of the language policy and teacher education programmes are proposed to resolve the problems faced by the English-medium students.

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CHAPTER 1

THE ISSUE OF MEDIUM OF INSTRUCTION AND LANGUAGE POLICIES FOR SECONDARY SCHOOLS IN HONG KONG

The medium of instruction in secondary schools has long been a controversial issue in Hong Kong. Before 1998, individual schools were free to decide their own instruction medium. As there is a great societal demand for graduates with high English proficiency, most schools opted for English as the medium of instruction without considering whether their students were capable of learning effectively through English or not. Starting from 1998, however, the government imposed a language policy for schools, which stipulates that most schools have to adopt Chinese as the medium of instruction, and only about a quarter of the schools which take in the more able students are allowed to teach through English. As this policy will have far-reaching impact on secondary education in Hong Kong, the present study is launched to study the effects of this policy on the learning of science of students in the first three years of secondary schooling. This chapter provides a review of the past and present language policies in Hong Kong and an outline of this thesis.

INTRODUCTION

Hong Kong was a British colony from 1842 until its return of sovereignty to China in 1997. Since 1842, English has become the official language of the government, and starting from 1974, Chinese has also become an official language. The majority of Hong

Kong's population is Chinese, using Cantonese, a dialect of Chinese, as the language of daily communication. However, English is a prestigious language as proficiency in English provides the means for social, economic and academic upward mobility. The education system is therefore charged with the task of producing graduates who are proficient in both Chinese and English, and various language policies on the medium of instruction (MOI) for schools have been implemented for achieving this goal. The majority of primary schools are Chinese-medium, with English taught as a separate subject. Before 1998, secondary schools were given the autonomy to choose the language medium for their students, and about 90% of the secondary schools used English as the medium of instruction (EMI) for all subjects except Chinese and Chinese History. The remaining schools opted for Chinese as the medium of instruction (CMI). Thus most students had to switch from Chinese to English as the MOI when they started their secondary schooling, irrespective of whether their proficiency in English was adequate or not. It was hoped that, through such an immersion programme, the EMI students could develop high levels of English proficiency, which were essential for employment and further academic studies. Findings from local studies (Brimer, *et al.*, 1985; Cheung, 1984; Hirvela and Law, 1991; Johnson *et al.*, 1985; Johnson and Lee, 1987; Lai, 1991), however, indicate that many of the EMI students could not learn effectively in English, and there was no evidence that these students developed adequate English proficiency through immersion in English (p.10-11). In response to these problems, which were thought to be incurred by the unregulated use of EMI in schools, the government decided to enforce a new language policy for the secondary schools in 1998. In the *Medium of Instruction Guidance for Secondary Schools* (hereafter referred to as the *Guidance*) issued by the Education Department, the educational benefits of mother tongue teaching are spelt out as follows (Education Department, 1997):

> With the use of Chinese as MOI lifting language barriers in the study of most subjects, students will be better able to understand what is taught, analyse problems, express views, develop an enquiring mind and cultivate critical thinking. Mother-tongue teaching thus leads to better cognitive and academic development. Our students can also have more time to concentrate on the learning of English.

These statements underlie the principle of the *Guidance* in assigning most secondary schools to CMI (i.e. 307 schools) and only 114 schools to EMI. It is envisaged that the EMI students, being identified as capable of learning effectively in English, can develop high levels of English proficiency through learning academic subjects in English, while the CMI students can learn academic subjects effectively in their mother tongue. This policy can exert far-reaching effects on the schooling system of Hong Kong. To understand its possible impact and implications, it is necessary to review the past and recent situations of MOI in Hong Kong schools before the implementation of the new MOI policy in 1998.

THE ISSUE OF MEDIUM OF INSTRUCTION IN HONG KONG

The majority of Hong Kong's population is Chinese, with Cantonese as the lingua franca. However, English has become a language of power as proficiency in English would confer a great advantage in securing well-paid posts in the government and the commercial section. This high status of the English language is reflected in the education system which aims at producing bilingual and biliterate graduates in both Chinese and English. Various government policy reports on education have reiterated that '... there is a need in Hong Kong to enhance the level of proficiency in both Chinese and English in order to satisfy the economic, political, educational and cultural demands that are being placed on individuals and the community as whole' (Education Commission, 1995: p.14).

The primary schools use Chinese as the MOI and teach English as a subject. When students graduate at Primary 6, the last year of primary education, they are streamed according to the medium of instruction into two types of secondary schools, the EMI and CMI schools. Before 1998, the secondary schools were free to choose their medium of instruction, and most schools opted for EMI to meet the high demand from parents who believed that their children would become proficient in English through receiving instruction in English. Some local studies (e.g. Kwan, 1989; Moh, 1992) have shown that this mode of late immersion is problematic because many students entering English-medium schools were not equipped with an adequate level of English proficiency for them to comprehend curriculum materials written in English.

Furthermore, some teachers in content subjects could not teach proficiently in English. An unplanned outcome of this situation is that many teachers use a mixture of Cantonese and English for instruction (Johnson, 1983; Shek *et al.*, 1991), or mixed code teaching.

Mixed code teaching had become more prevalent in the secondary schools in the last two decades since the implementation of nine-year compulsory education from primary 1 to secondary 3 (grades 1 to 9) in 1978. Learning through English was beyond the language ability of the majority of students. In many of the English-medium schools that took in the less able students, the teacher used Cantonese most of the time for teaching, classroom control and interpersonal interaction. Interaction in English was mainly restricted to asking simple recall questions that required one-word or single-phrase answers from students, highlighting vocabularies in English textbooks with explanation in Cantonese, or going through worksheets or notes written in English (Johnson, 1997; Pennington, 1999; Evans, 2000). The weakest students could not understand even very simple text written in English. Their style of learning basically consisted of translating content words in a text written in English by looking up the dictionary and writing down the Chinese characters alongside the English vocabularies in their notes or textbooks. In order to prepare for tests and examinations, they had to commit to memory terms and isolated chunks of texts in English that they did not fully understand. In such conditions, it was very unlikely that these students could develop an intrinsic interest and motivation in learning. Given the poor English standard of the students as well as the pressure to cover syllabuses heavily loaded with factual content, teachers considered the use of Cantonese and mixed code for classroom instruction as inevitable or even desirable. This situation was also prevalent in some of the schools that have better student intake.

The claim that the mother tongue is the best medium of learning has been substantiated by some local studies. For example, in a study involving about 800 students at the S3 level (14 years old), Lo (1991) reported that the performance of Chinese-medium classes on a standardised mathematics test was superior to that of English-medium and mixed-medium classes. In a recent study conducted by Tse and his co-workers (2001) that involves surveys, interviews and case studies on teachers and school administrators, it was found that most teachers believed that mother-tongue instruction motivates students to learn, encourages students to continue to a higher level of education, and raises the quality of education. School administrators also reported that the overall academic results of their students improved after changing to CMI. Despite the positive effects demonstrated by learning through the mother tongue, the education system must produce graduates proficient in English as well as Chinese, so as to sustain the economic growth of Hong Kong as an international center in trading and finance. This dilemma of Hong Kong puts the government in a paradoxical position on the issue of MOI for schools. A review of the language policies for schools can illustrate the strategies taken by the government to resolve the dilemma of meeting the educational needs of students on one hand and the society's demand for biliterate graduates on the other hand.

LANGUAGE POLICIES FOR SCHOOLS

In 1963, Marsh and Samson (1963), appointed by the government to review local educational needs, concluded that using EMI imposed a heavy burden on students and recommended that there should be more CMI schools where English is taught as a second language. However, the government declined to take any action and gave the following reasons:

> We appreciate the importance to Chinese youth of making a thorough study of their own language and cultural heritage, and the educational advantages of learning through the mother tongue. Indeed, we consider that many of the pupils in Anglo-Chinese (*English medium*) secondary schools are unable to benefit fully from the education provided because of the difficulty of studying through the medium of a second language. Nevertheless, we are reluctant to endorse this recommendation in the face of marked parental preference for Anglo-Chinese secondary education, the fact that the English language is an important medium of international communication and that a knowledge of it has undoubted commercial value in Hong Kong. (Hong Kong Government, 1965: p. 83)

The government was fully aware of the advantage of learning through the mother tongue and the detrimental effects of learning through English. However, social and economic considerations were put forward by the government to override educational concerns.

In 1973, the Report of the Board of Education on the expansion of secondary education in Hong Kong put forward the following comment on the MOI issue:

> The medium of instruction bears significantly upon the quality of education offered at post-primary level. Pupils coming from primary schools where they have been taught in the medium of Cantonese have a grievous burden put on them when required to absorb new subjects through the medium of English. We recommend that Chinese become the usual language of instruction in the lower forms of secondary schools, and that English should be studied as the second language. (Hong Kong Government, 1973: p. 6)

The government did not adopt this recommendation, but again put forward the concerns of parental preference and economic development as justifications. There was, however, a shift in the government's position. Instead of turning down the recommendation, the government left the choice of medium of instruction to schools:

> On education grounds there are strong arguments for maintaining that the medium of instruction for children aged 12-14 should be Chinese. However, there are other considerations ... It is undeniable that Hong Kong, if it is to maintain its progress, will continue to need people at all levels in commerce, industry and the professions who are at home in English as well as Chinese. For these practical reasons, the standards of Chinese and English must be maintained, and indeed, if possible, improved, and parents are likely to demand that they should be ... It is the government's intention that individual school authorities should themselves decide whether the medium of instruction should be English or Chinese for any particular subject in junior secondary forms. (Hong Kong Government, 1974: p.7)

By allowing individual schools to choose their MOI and by allowing flexibility to vary the medium of instruction for different subjects, the government avoided making any commitment on the issue of MOI. Given that a good command in English was still an important factor for getting into the university, and securing a post in the civil service and workforce, the high status of English in schools was maintained. Most schools continued to opt for EMI, and the problems of learning in a second language, which affected many EMI students, remained unsettled.

In 1982, a panel of overseas educators conducted a comprehensive review of education in Hong Kong. They pointed out that it was unrealistic to use a second language for universal education in a largely monolingual society. The Llewellyn Report described the situation in schools as 'lamentable', and offered the following arguments against the use of EMI in secondary schools:

> Many Chinese speakers find it almost impossible to master English at the level of proficiency required for intricate thinking; and yet pupils from non-English speaking Chinese families have to express themselves in English at school. Under these conditions, more emphasis tends to be placed upon rote learning ... Many of the problems associated with schooling in Hong Kong – excessive hours of homework, quiescent pupils – are magnified, even if not caused, by the attempt to use English as a teaching medium for students. (Llewellyn *et al.*, 1982: p.26-27)

The Llewellyn Report suggested that the mother tongue is the best medium for teaching and learning. However, to resolve the dilemma on the MOI issue, it proposed the following curriculum outline as a compromise: Mother tongue should be used in the early compulsory years and, starting from S1, the first year of secondary education, there would be a progressive shift to bilingual programmes with half of the subjects taught in English and half in Chinese by S3 (grade 9). Given the low levels of English proficiency achieved by students at the end of primary education, the Report believed that a late partial immersion programme was more appropriate for Hong Kong schools than a total late immersion programme. Although the recommendations proposed were not adopted directly by the government, the observations made in the Llewellyn Report were constantly referred to in subsequent studies on the language policy for schools.

After the Llewellyn Report, the government maintained the status quo by allowing individual schools to choose their MOI. However, in order to encourage schools to shift to Chinese medium, additional resources were given to CMI schools to strengthen English teaching, such as the provision of additional English teachers to allow for small class teaching and guidelines to help schools to decide on the medium of instruction according to their S1 student intake (Education Commission, 1984). Meanwhile, research findings provided further evidence for the negative effects of using English as a medium of instruction for students with low English proficiency. For example, Cheung (1984) showed that most of the secondary students entering English-medium schools had a low vocabulary level and grammatical competence in English and they were unable to read textbooks of content subjects with understanding. Brimer *et al.* (1985) also demonstrated that about 70% of junior secondary students were disadvantaged by learning History and

Science through English. At S3 level (14-year olds), Johnson and Lee (1987) showed that more than 25% of students in English-medium schools could not answer basic factual questions on a simplified English text. Lai (1991) reported that many of the less able students in EMI schools were essentially illiterate in English despite having learned English as a subject for six years at primary level. They could identify some individual words but were unable to read or understand the most elementary text which was written in English. Johnson and Yau (1996) described the reading strategies used by the weaker EMI students as lexically-based translation. A common survival strategy used by these students was to identify the Chinese equivalent of the content words in a text written in English using a bilingual dictionary and then construct a meaning around the Chinese characters, which might be quite different from the original. The frequent use of such a strategy also tends to inhibit the development of second language skills. The notion that many EMI students do not possess adequate English proficiency is also supported by the results of an international study which show that the reading ability of Hong Kong students in English was far lower than that in Chinese (Hirvela and Law, 1991).

An implication from these findings is that it was unjustified to allow the schools or the parents to decide on the MOI of schools, as the majority of students studying in EMI schools were found to fail to learn effectively through the English medium. However, despite the provision of positive discrimination for CMI schools by the government and the clear evidence for the advantage of learning through the mother tongue, most secondary schools continued to use EMI for their students.

In the 1990s, the Education Commission, which advises the government on all major educational policies, began to realise that students could not acquire the high levels of English proficiency required by society through the current practice of late immersion with mixed code teaching in the EMI schools (Education Commission, 1990). The Commission acknowledged that the dilemma for Hong Kong education lies in that "there is a pressure for children to learn English, since this is seen by parents as offering the best prospect for their children's future. Many children, however, have difficulty with learning in English; and conversely, Chinese is undervalued as a medium of instruction" (Education Commission, 1990: p.93). It believed that for most students, learning occurred most effectively in the mother tongue, and the uncontrolled intake of students into the English-medium stream had seriously jeopardised the educational development of the less able students, who did not have the basic language proficiency or motivation for learning content subjects in English. In order to gain benefit from instruction in English, students must have reached a threshold level of proficiency in both their mother tongue and English.

For the first time, the government showed a determination to resolve the issue on the medium of instruction by adopting the recommendations made by the Education Commission in 1990. It was felt necessary to implement a more directive policy on the medium of instruction for secondary schools progressively starting from 1994 (Education Commission, 1990). Besides advising individual schools on the language medium to be used, the government laid down a time-line for schools to make preparations for the transition to the language medium appropriate for their students. From 1994-1997, advice would be given to schools on the medium of instruction based on the ability of their S1 intake, although schools would still have the freedom to choose the language medium. From 1998 onwards, schools would have to follow strictly the government's advice on the choice of medium of instruction.

IMPLEMENTATION OF A NEW LANGUAGE POLICY IN 1998

Aiming to resolve the long-standing problems associated with the unregulated adoption of EMI in secondary schools, the government put forward the *Guidance* to enforce the language policy for schools in September 1997, shortly after the return of sovereignty over Hong Kong from Britain to China (Education Department, 1997). Under the directives of this *Guidance*, the government will determine the instruction medium for the junior secondary level of individual schools according to the schools' S1 student intake, instead of allowing the schools to choose their own medium. Starting from 1998, Hong Kong secondary schools will be streamed into EMI or CMI according to the grouping of their S1 entrants in the Medium of Instruction Grouping Assessment (MIGA). It is hoped that this policy will ensure schools to use the MOI most appropriate for their students.

The MIGA grouping of a student is based on his or her performance in internal school assessments in two subject groups, Chinese and English, in the last two years of primary schooling, i.e. P5 and P6. The 'Chinese subject group' comprises all subjects taught in Chinese (excluding cultural subjects and Physical Education) and the 'English subject group' comprises only English Language for most students. In order to ensure comparability across all schools, the internal assessment scores are scaled by a public examination, made up of a Chinese proficiency test and a Mathematics proficiency test, administered to all students at the end of P6. With reference to the MIGA, primary school graduates are classified into the following groups:

Group I: those in the top 40% in both subject groups, who are supposed to be able to learn effectively through either Chinese or English;

Group II: those not in the top 40% in either subject group, who are thought to be able to learn more effectively in Chinese; and

Group III: those in the top 40% in one subject group and the top 50% in the other, who are thought to be able to learn better through Chinese, but probably can also cope with English medium instruction.

Secondary schools are allowed to opt for EMI if they satisfy the following requirements deemed necessary for effective instruction in English:

- not less than 85% of the students belong to Groups I and III;
- teachers should be capable of teaching in English; and
- support strategies are available to help students learn effectively in English.

The principle of assigning secondary schools into the EMI stream according to the MIGA of their students is thus mainly based on general academic ability of their S1 students, rather than on criteria that can predict success in English medium instruction.

Many public responses consider that MIGA is not a fair and reliable basis for predicting whether a student is suitable for receiving instruction through English or not, but suggest that there is a need to have an independent test for language grouping (Education Commission, 1995: p.36).

Subsequently, most secondary schools are required by the authority to use CMI for their junior years starting from the school year 1998/1999, and 114 secondary schools have been approved to use EMI. Under this new language policy, it is hoped that most students can learn content subjects effectively in their mother tongue and more study time can be devoted to raising their standards in the two languages. Some of these students may be allowed to use EMI at a later stage (S4 or above) if there is evidence that they have reached a certain threshold of English proficiency. On the other hand, the most able students with adequate English proficiency, being streamed into the EMI schools, follow a total immersion programme in English.

The *Guidance* also stipulates that schools should follow their assigned medium strictly, and discourages the mixing and switching mode of instruction. Thus for the EMI schools, English is the predominant language of oral and written instruction for all subjects except Chinese and Chinese History. In the past, mixed-mode teaching had been excused as unavoidable or even necessary, given the problems of a need to cover the intensive syllabuses and the limited English proficiency of the students and sometimes of the teachers. The Education Commission reported that in many English-medium schools, teachers often used Cantonese to explain English lesson materials and to conduct discussions with students (Education Commission, 1990: p.100). This kind of practice might lead to loss of lesson time in translating English texts in class and learning reduced to rote memorization of facts. By restricting the use of English medium to schools that take in students with adequate English proficiency and by eliminating mixed-mode teaching, the new language policy is an attempt to legislate for total immersion in English in the EMI schools, thereby providing opportunities for students to achieve high levels of proficiency in the second language.

THEME OF THE PRESENT STUDY

In order to explore the impact and implications of this language policy, the Education Department has commissioned the Faculty of Education of the Chinese University of Hong Kong to conduct a research project to study the effects of the language policy laid down in the *Guidance* on the achievement of EMI and CMI students in Chinese, English, Mathematics, Social Studies and Science. The findings of this project will provide important guidelines for shaping the language policies for the schools in Hong Kong. They will also contribute to understanding the impact of language immersion strategies on student learning, particularly in relation to total immersion programmes that begin in secondary schools.

The work reported in this thesis is a part of that large-scale project. It involves a longitudinal study that focuses on the effects of MOI on the science achievement of students in the first three years of secondary education, with special reference to the effects of total immersion in English. In order to contextualise the study and provide an overview of the rationale of its design, the next chapter will review relevant literature on language immersion programmes, particularly those related to the learning of science and other content subjects. The subsequent chapters will describe the methodology of the study, and analyse the data obtained on different aspects of science learning in relation to the medium of instruction. The last chapter will discuss the implications of the findings with reference to the research questions formulated, as well as proposing recommendations for the implementation of the new language policy for Hong Kong schools.

CHAPTER 2

LITERATURE REVIEW ON IMMERSION MODELS AND THE LANGUAGE POLICIES IN HONG KONG

INTRODUCTION

There is general agreement that it is the responsibility of the education system in Hong Kong to produce graduates who are proficient in Chinese and English in order to ensure sustained economic growth (Llewellyn *et al.*, 1982; Education Commission, 1990; Education Department, 1997). One means to achieve this is through the use of English as the medium of instruction for the native Chinese-speaking students in secondary schools. It is believed that learning content subjects through a second language (L2) can help students achieve additive bilingualism, thus implying a high level of proficiency in the second language with no loss in the development of the mother tongue (L1). This approach for promoting the acquisition of a second language is known as immersion, and has been widely practised in different school systems of the world, particularly in places like Hong Kong where the target language is rarely used by students outside the classroom. The main principle of immersion is to use the target language to teach academic subjects within the regular school curriculum. By integrating second language learning with academic instruction, it is expected that students will learn the target language in much the same way that they learn their native language, and they will be able to use L2 to communicate and discuss their ideas in a meaningful way within the domain of specific academic subjects. To review the rationale and implications of immersion education in the context of Hong Kong, particularly with regard to the language policy stipulated in the *Guidance*, this chapter is divided into two parts. Firstly, there is a review of relevant literature pertaining to the nature of immersion programmes and their effectiveness in promoting the development of competence in L1 and L2. Secondly, the effects of the medium of instruction on the learning of content subjects are considered, including the potential impact on students' academic self-concepts.

PART I: LITERATURE REVIEW ON IMMERSION EDUCATION

The term "immersion" was first adopted in the 1960s for the school programmes conducted in Quebec in which native English-speaking children were taught through the medium of French (Lambert and Tucker, 1972). This term is now used to cover a variety of situations in which a second language is used as the medium of instruction for content (non-language) subjects. Examples are the French immersion programmes in Canada, the Catalan and Basque immersion programmes in Spain, the immersion programmes in English and other colonial languages in African countries, the English immersion programmes in Hong Kong and Singapore, and the various immersion programmes in Korean, Russian, Japanese and Spanish in the United States for native English-speakers (Swain and Johnson, 1997). A common aim of immersion programmes is to promote the development of a higher level of proficiency in a second language than that can be achieved when it is taught as a language subject. Thus for example, immersion programmes were introduced as a response to the ineffectiveness of traditional curricula in promoting second language acquisition in Canada. In the U.S., Canada, Australia, and many countries in Europe and elsewhere, most school children receive their education through their home language, and learn a second language as a separate subject. This approach does not extend to producing fully bilingual and biliterate children (LeBlanc, 1992), and the great majority of students only develop a very limited form of fluency in the second language, which quickly degenerates after leaving school. On the other hand, by using L2 as the medium of instruction, children will have much greater exposure to L2 and are more likely to acquire the intended language skills through using it functionally and meaningfully in the context of a range of content subjects. With this approach, there will be a greater chance for children to succeed in achieving high levels of proficiency in L2.

The aim of learning L2 through immersion may vary according to the needs of different communities, such as enhancing second language learning (e.g. English-speaking children in Quebec learning French), reviving a language at risk (e.g. Spanish-speaking children in Spain learning Catalan), or mastering a language of power (e.g. Chinese-speaking children in Hong Kong learning English). Examples are described below to illustrate the commonality and variations among immersion programmes, in relation to the specific contexts and demands of different communities, and to make implications on the language policies implemented in Hong Kong.

French immersion programmes in Canada

In the 1950s, the Canadian province of Quebec was made up of a French-speaking population and an English-speaking population, each with its distinct culture and social status. Although the French Canadians were in the majority and French was the official language, the English speakers knew little of the language. They might have studied French in school as a subject, focusing on grammar, drill and memorisation, but their French did not reach a level of proficiency that would enable them to work in French or to socialise with the French speakers (Swain and Johnson, 1997). By the mid-1960s, the English speakers were becoming aware of the economic advantage of acquiring high levels of proficiency in French. This situation prompted a group of parents in St Lambert, Quebec, to request their local school board to strengthen the teaching of French as a second language. Instead of offering French as a language subject, they proposed a programme in which their English-speaking children would be instructed entirely in French in the first three years of schooling, starting from kindergarten. English was introduced into the curriculum in the second or third grade, and by grade 6 about half of the curriculum was taught in English and half in French. The parents and the school board labelled this programme as an immersion programme, distinguishing it from other forms of bilingual education in which the second language was taught only as a subject (Lambert and Tucker, 1972). In this immersion model, learning French becomes incidental and subconscious as the teachers and children use it for communicating subject matter in a meaningful and relevant way.

One of the main concerns of parents and educators on immersion is that the development of L1 skills might be negatively affected, as the exposure time to L1 was greatly reduced. This worry was dispelled by the findings of a number of studies (e.g. Cummins, 1979; Genesee, 1978; Lapkin and Swain, 1977), which showed that the immersion students lagged behind the non-immersion students in English language abilities in the first four years, but had caught up with their non-immersion peers with increased years of schooling. By the end of the primary schooling, after about six years of schooling, there is no difference in L1 development between both groups of students. On the other hand, most of these immersion students showed native-like performance in French in the receptive language skills of listening and reading, and to a lesser degree in the productive skills of speaking and writing (Lapkin *et al.*, 1990). These findings provide evidence that immersion students can learn a second language at no cost to their first language.

Taken together, these findings indicate that immersion programme conducted in St. Lambert was effective in promoting the development of high proficiency in L2, with little detrimental effect on the acquisition of L1 language skills. The immersion students might suffer an initial lag in L1 development, but would catch up the non-immersion students with increased years of schooling.

Success of this programme had led to a multiplication and spread of French immersion programmes across Canada, with variations in the format of implementation according to the needs and concerns of the local communities (Cummins, 1991a). A variety of modified models have been developed to address the concerns about the lag in L1 acquisition. For example, in early partial immersion programmes, some academic subjects are taught in English and some in French starting from grade 1; in delayed immersion programmes, instruction through French starts at grade 4 or 5; in late immersion programmes, immersion in French starts at grade 6 or 7 (Cummins, 1991b; Genesee, 1983; Swain, 1984). In these models, English language skills were introduced right at the beginning so that the possible negative effects of early total immersion programme on the development of L1 literacy skills could be reduced. Like the early total immersion children, early partial immersion children also tend to lag behind for three or four years in their English language skills, but catch up with the non-immersion children in English language achievement by the end of primary schooling. Similarly, late immersion has no long-term negative effects on English language skills (Genesee, 1983). It is interesting to note that the final performance of early and late immersion students on second language tests appears to be equivalent. This finding is somewhat unexpected given that the early immersion students have considerably more in-school contact time in French. An interpretation of this result is that older students tend to learn a second language more effectively than younger learners, particularly in literacy-related and literacy-supported language skills. According to the developmental interdependence hypothesis (Cummins, 1979; Cummins and Swain, 1986), a child's L2 competence is partly dependent on the level of competence already achieved in L1, and proficiency in L1 will facilitate the development of L2 provided there is adequate exposure to L2 and adequate motivation to learn L2.

Based on the studies on the Canadian immersion programmes, the following conclusions will be helpful in understanding the impact and effectiveness of the MOI policies of Hong Kong:

1. Immersion students achieve higher levels of proficiency in L2 than non-immersion students.
2. Late immersion has no long-term negative effects on L1 proficiency.
3. Proficiency in L1 will facilitate the development of L2.

Revival of languages at risk in Spain

Spanish is the dominant language in Spain, since some of the heritage languages, such as the Catalan and Basque, had been banned from schools for some time. Although these minority languages were still used as home languages in some communities, they were at risk of extinction because more and more children were learning the dominant language as a first language. This policy had led to discontent, resentment and divisiveness among different populations. As a remedial action to resolve the political and social divisions, immersion programmes have been established in Catalonia and the Basque Country to support the revival of the at-risk native languages (Artigal, 1997; Arzamendi and Genesee, 1997).

Over the last two decades, Catalan has been reinstated in Catalonia as the main medium of instruction for Catalan speakers and as an L2 medium of instruction for many Spanish-speaking children, starting from the very beginning of kindergarten. Various models have been experimented. However, in 1993, one single model for kindergarten and primary schools was introduced. Catalan is used as the main medium of instruction, with compulsory Spanish language and one content subject taught in Spanish from grade 3 (8 years old), and two content subjects in Spanish from grade 6 (10 years old). Thus an early partial immersion model is used in Spain for reviving a heritage language while at the same time maintaining the dominant language. According to Arenas (1994), when two groups of grade 3 Spanish-speaking students of similar IQs and home socio-cultural backgrounds were compared, the immersion students showed a better achievement in Catalan than the non-immersion students. The immersion students got lower scores in written Spanish than the non-immersion students at the end of grade 3, one year after immersion, but there were no significant differences between the two groups at grade 5. A general outcome of the immersion programme is that, after several years of immersion, the students acquire competence in both L1 and L2 without any adverse effects on their cognitive and academic development (Artigal, 1997). This finding is consistent with that of the Canadian immersion programmes. The success of this immersion programme in developing L1 and L2 proficiency has been attributed to high-quality pedagogical interactions. The immersion teachers are proficient in Catalan, and they master methods for meaningful and effective classroom interactions (Artigal, 1991).

Since the passing of the 1983 law on school language which establishes the use of the Basque language in primary and secondary schools in the Basque Country, several language models have been implemented in schools. These include a programme in which Spanish is the instruction medium and Basque is taught as a subject, an immersion programme in which both Basque and Spanish are used as the medium of instruction, and a total immersion programme in which Spanish-speaking and Basque-speaking students learn content subjects through Basque and learn Spanish as a subject (Lasagabaster, 2001). In the past two decades, there has been a change from a dominant non-immersion system to the acceptance of a variety of immersion systems. Student enrolment numbers for the partial and total immersion models are steadily increasing. This shift in parental preference for the immersion programmes may well be influenced by empirical findings which show that the immersion approach is more effective in developing competence in L1 and L2 than the traditional approach. Research studies conducted by Lasagabaster (2001) and Lasagabaster and Cenoz (1998) demonstrate that non-immersion students develop low proficiency in Basque, partial-immersion students acquire a higher level of competence in Basque, and total-immersion students attain the highest competence in Basque. Regarding student competence in Spanish, the majority language, these studies show that there is no significant difference between the three student groups, despite the fact that the non-immersion students spend more time using Spanish in school. It thus appears that the extensive exposure of all students to Spanish in the community, through the mass media or daily communication outside school, is a key factor in attaining a high level of competence in Spanish. These results indicate that immersion students became proficient in Basque without detriment to the development of Spanish language skills by learning through the medium of Basque (Arzamendi and Genesee, 1997).

Based on the studies on the Spanish immersion programmes, the following conclusions will be helpful in understanding the impact and effectiveness of the MOI policies of Hong Kong:

1. Immersion students achieve higher levels of proficiency in L2 than non-immersion students.
2. The level of L2 proficiency increases with the degree of immersion.
3. The immersion students achieve the same competence in L1 as the non-immersion students, as extensive exposure to L1 in everyday life will compensate for the less lesson time on L1 in school.
4. The success of immersion in developing L1 and L2 proficiency is attributed to high-quality pedagogical interactions in the classroom.

Immersion in an international language in African countries

In Namibia, a country in southwest Africa with a population of 1.5 million, there are officially thirteen languages of instruction in the early years of schooling. Among these are three European and ten African languages. Namibia was colonized by the Germans from 1884 to 1914, and German is still an important business language in Namibia today. During the South African rule until 1990, Afrikaans, a variety of Dutch, became the main official language and the language of instruction from grade 4 upwards. After independence, English was established as the main official language of Namibia through the support of overseas agencies such as ODA and US-Aid (Brock-Utne, 1997;

Holmarsdottir, 2000). English is used as a medium of instruction in schools. Thus an early total immersion model is used for promoting proficiency in a second language, which is an international language for business, science and technology. The growth and domination of English as a language of instruction has not only led to the decline of Afrikaans, which is an intended consequence, but also the decline of Namibian languages. People are developing a negative attitude towards their native languages, and those who can speak English are regarded as better educated than those who only speak Namibian languages. Brock-Utne and Holmarsdottir (2001) express the concern that, if this situation continues, Namibian society will become highly stratified with an elite group speaking English and the masses using their mother tongues. Instruction in English has also created serious learning problems in schools because of the low English proficiency of the students as well as the teachers. The learners prefer to use their own native language for instruction since this is the medium they understand. However, most parents prefer their children to be taught in English as proficiency in this language is associated with a higher social status and provides better employment opportunities (Beck, 1994; Phillipson, 1992). In order to revive the native languages and to promote more effective learning, trial programmes that use Namibian languages as the languages of instruction for the whole of primary school have now been implemented, with English taught as a subject.

The language policy of Namibia reveals some of the problems associated with an early total immersion programme when no consideration is given to the conditions required for its successful implementation, such as the need for students to develop basic proficiency in their native language before starting immersion, and for teachers to possess sufficient English proficiency. Similar conflicts between declining indigenous languages and dominant colonial languages are found in a number of African countries after gaining independence from their former colonial governments, such as Malawi, South Africa and Cameroon. Schools in these countries seldom use the native languages of the children for instruction. In general, the language of instruction is one of European origin, most often English or French, which is also the official language. This situation has created two social classes, the elite and the masses. The civilised elite can speak and write the official language, but are illiterate of the native languages. Therefore, they cannot communicate effectively with the masses. In order to maintain cultural heritage and at the same time promote communications within members of the same ethnic community, with other communities and at the international level, it is important in these contexts that students should master their native languages as well official languages both orally and in writing. The native language provides a means for retaining cultural heritage and for communication at home among people of the same ethnic group, while the official language serves as a language for promoting international trade and economic progress. To achieve these aims, these countries adopt a strategy that is very similar to that on trial in Namibia. Instead of using an early total immersion approach, the native language is used as the medium of instruction in the early grades, while the official language is taught as a subject (Gfeller and Robinson, 1998; Heugh, 1999; Reinhard, 1996). Thus in many African countries, a shift from early immersion to late immersion is considered to be a more effective strategy for children to achieve proficiency in L1 and L2.

Comparing the African experience with the successful immersion programmes in Canada and Spain, the following implications can be made about the problems of immersion:

1. Early immersion students may develop low proficiency in L1 if they do not have the chance to use or develop it outside school.
2. Low L2 proficiency of students and teachers tends to impede learning through L2.
3. Late immersion is more preferable than early immersion for the African countries as it ensures that students have acquired basic proficiency in L1 before immersion in L2.

Immersion in a language of power in Singapore

Singapore is a multicultural society with a rich linguistic tradition. Based on the 1990 census, its total population of three million consisted of a majority of ethnic Chinese (76.3%) and minority groups of Malays (15%), Indians (6.4%) and others (2.3%). Although Chinese is the language of the majority, it was not adopted as the national language. Instead, the government adopted Malay, which was spoken by only 15% of the population, as the national language. An important reason for not using Chinese as the national language is that the Chinese majority were mainly immigrants from China who showed a strong affiliation with China (Yip and Sim, 1990). Using Chinese as the national language would make it difficult for Singapore to establish its own national identity. To ensure that no ethnic group would be disadvantaged, English, Chinese, Malay and Tamil were designated as official languages.

To ensure the economic development of Singapore, a supply of graduates who are proficient in English as well their native language are needed. To achieve this, English is used as the medium of instruction at all levels of formal education, from primary through secondary to tertiary education. The native languages of the children, such as Chinese, Malay and Tamil, are taught as subjects. According to this early total immersion policy, it is important for children to develop English proficiency at an early stage which will determine their educational future and success (Eng *et a*l., 1997). Although not a native language of the major ethnic groups, English is a language of power providing opportunities for higher education and better careers, as in the case of a number of African countries and Hong Kong.

The dominance of English in Singapore is the result of a carefully-planned language policy. English not only serves as a language for promoting international trade and economic progress, but also provides a common language among different ethnic groups to foster inter-ethnic communication and develop a Singaporean identity (Gopinathan, 1994). On the other hand, native languages provide a means of retaining cultural heritage and for communication at home and among people of the same ethnic group (Eng *et al.*, 1997). In less than 20 years since its independence, English has become far more important than the other three official languages, and has virtually replaced Malay as the national language. English is the dominant working language for business and trading on one hand and, being an ethnically neutral language, is the best vehicle for reducing ethnic tensions and building a multilingual society (Chang, 2002; Tickoo, 1996).

The language issues faced by Singapore and Hong Kong share some common features. Both were British colonies, with English established as a language of power, and majority of the population are Chinese. However, the two places address the language issue in different ways. In Singapore, early total immersion in English is implemented to promote the development of high levels of English proficiency in children, at the expense of marginalizing the native languages and culture of the different ethnic groups. In Hong Kong, a late immersion model is preferred so that children will be able to achieve a basic proficiency in Chinese during their primary schooling before going into the immersion programme. It is expected that the immersion students will be able to develop a national and cultural identity as well as achieving competence in Chinese and English.

The following implications drawing from the Singaporean experience can provide useful feedback to the design of immersion model in Hong Kong:

1. Early total immersion promotes the development of high proficiency in L2.
2. Early total immersion may be detrimental to the development of L1 proficiency and ethnic identity and culture.

Summary of conclusions and implications from different immersion programmes

Before embarking on the issues of immersion in Hong Kong, it is appropriate to summarise the experiences gained from the studies on different immersion programmes that are relevant to Hong Kong. These conclusions and implications can inform the formulation of language policy in Hong Kong. They can be grouped according to the following issues:

1. Early or late immersion

- Immersion students achieve higher levels of L2 proficiency than non-immersion students.
- Late immersion has no long-term negative effects on L1 proficiency, particularly if the immersion students are exposed extensively to L1 in everyday life.
- Early immersion may be detrimental to the development of L1 proficiency and ethnic identity
- Late immersion is more preferable in some situations as proficiency in L1 will facilitate L2 development.

2. Total and partial immersion

- L2 proficiency increases with the degree of immersion.

3. Code switching

- Low L2 proficiency of students and teachers tends to promote code switching which impedes development of L2 language skills through immersion.

- High-quality pedagogical interactions is essential for the success of immersion in promoting L1 and L2 proficiency.

These findings provide a framework for considering the issues of immersion in the context of Hong Kong.

Issues of immersion in Hong Kong

1. Rationale for a late immersion model

According to the research studies reviewed in the previous section, different models of immersion in various countries have been found to be effective in developing L2 proficiency in children, in comparison with learning L2 as a separate subject. Early immersion has worked successfully in the Canadian and Spanish programmes. Late immersion, an alternative model of immersion, however, has also been found to be effective in some Canadian regions and African countries.

As described in Chapter 1, Hong Kong schools have consistently opted for the late immersion model instead of early immersion. Most students in Hong Kong switch their medium of instruction from Chinese to English after completing primary schooling. While the change of instruction medium becomes more difficult for students the later it occurs (Johnson and Swain, 1994), late immersion has the advantage that students would have achieved adequate proficiency in L1 before switching to L2. In this way, the possible negative effects of early immersion on the development of L1 proficiency can be avoided.

This mode is considered to be more conducive to the development of L1 and L2 in the context of Hong Kong. In the Canadian early immersion model, where English (L1) and French (L2) are quite similar in linguistic structure, proficiency in L2 can facilitate the development of L1 (Cummins and Swain, 1986). However, in the case of Hong Kong, Chinese (L1) and English (L2) are linguistically unrelated and the writing systems are totally different. The Chinese language, with its complex literacy system, takes even native speakers many years to acquire. Thus the learning of English is not likely to facilitate the development of Chinese. Rather, due to competition in lesson time for L1 and L2 in immersion programmes, proficiency in one language may be achieved at the expense of the other.

The negative effects of early immersion on the development of L1 has been demonstrated by the experience of some African countries (p.28-29) and Singapore (p.31). This is why Hong Kong advocates a late immersion model in which the native Chinese-speaking children will focus on developing Chinese language proficiency in the primary school years before switching to English as a medium of instruction in the secondary levels. According to the Canadian findings, when students have acquired L1 competence, immersion in L2 will have little negative effects on the further development of L1 language skills as a result of reduced exposure time to L1, since L1 is used by the students in everyday communication and social interaction inside and outside the school. Late immersion programmes have been successfully implemented in Canada and some African countries. In these cases, the late immersion students reach the same level of L1 proficiency as the non-immersion students, and their final achievement in L2 literacy skills is equivalent to that of the early immersion students (p.23 and 29).

2. Total or partial immersion

Another issue of immersion faced by schools in Hong Kong is whether total or partial immersion should be adopted. In total immersion, L1 is taught as a subject and L2 is used a medium for teaching content subjects, whereas in partial immersion, L2 is used as the medium for only one or a few content subjects. In Canada and Spain, partial immersion programmes often start in the primary schools, with an aim to strengthen L1 development at an early stage of schooling. This mode is not relevant to Hong Kong schools which practise late immersion so that students will have achieved L1 competence before switching to L2 for instruction. The Philippines also offer partial immersion programmes, in which Filipino is used for learning social studies subjects and English for studying science and mathematics. This approach helps to promote parallel development of the national language and the second language, and is also a concession to the low English proficiency of the students and teachers (Gonzalez and Sibayan, 1998).

In the 1990s, many EMI schools in Hong Kong were moving towards a partial immersion approach. According to a survey conducted by Shek and her co-workers (1991) that involved 193 schools, about 30% of the schools that claimed to be English medium adopted a flexible policy in junior secondary classes, in that Chinese was used for some subjects and English for others. These schools were those that took in students of lower academic abilities. As in the case of the Philippines, the adoption of partial immersion by these schools was a strategy to compromise for the low English proficiency of their students. Subjects chosen to be taught in Chinese generally included Social Studies and EPA (Economics and Public Affairs), probably because the learning of these two subjects makes a high demand on language skills. The Education Commission (1990), however, pointed out that this practice was not in students' best interests and discouraged its adoption in schools.

The efficiency of partial immersion was also challenged on the ground that a reduced exposure and usage of English would lead to the attainment of lowered proficiency levels in English. Total immersion, on the other hand, maximizes the extent and intensity of the use of English across the curriculum. This is particularly important for the late immersion programme adopted in Hong Kong where immersion starts at the junior secondary years. However, to make late total immersion work successfully, it is necessary to ensure that at the start of the immersion programme, the students have acquired the language skills that enable them to learn effectively through English across the curriculum. The guidelines laid down for EMI schools in the *Guidance* (Education Department, 1997) are probably based on such considerations. For example, all EMI schools have to adopt total immersion in which English is used as the medium for all subjects except Chinese and Chinese History. Moreover, the EMI students are selected for their higher academic and language abilities in order to benefit from immersion education. While this selection policy is made on educational grounds, it is often viewed by parents and teachers as a means of discrimination that promotes elitism and divisiveness among schools and students.

3. Mixed code teaching in English-medium schools

A recurrent issue concerning immersion education in Hong Kong is whether Chinese should be used in the classroom as a supplement to English as a medium of instruction. Using a mixture of L1 and L2 for instruction is a characteristic of immersion programmes in places where the students, and sometimes the teachers, are constrained by their limited proficiency in L2, such as in the Philippines (Ibe and Coronel, 1995) and Malawi (Reinhard, 1996). Before the implementation of the new language policy in 1998, most secondary schools that claimed to be English medium used mixed code teaching, i.e. using a mixture of Cantonese and English in the classroom. A study that involved 15 EMI teachers teaching S1 to S3 showed wide variation amongst schools, teachers and even between lessons taught by the same teacher in the amount of English used in instruction (Johnson, 1983). The teachers in this study used 43% English, 48% Cantonese and 9% mixed code and individual lessons varied from 100% English to 2% English. Subsequent studies that involved several hundred teachers showed an increase in the use of Cantonese and mixed code across S1 to S7 (12-19 years old). Particularly in A-level mathematics and science subjects, the lessons were dominated by Cantonese inserted with English terminology and only 10% of the teaching was in English (Johnson *et al.*, 1991). Schools with the top 20% students showed the highest levels of English use, while schools with the bottom 50% students tended to use very little English. In certain cases, mixed code is used as a strategy to enable students with low levels of English proficiency to survive a curriculum in which the subject matter and assessment are presented in English. Even for high ability students with adequate English competence, mixed code is often used at senior secondary levels to facilitate the understanding of abstract and complex concepts.

According to the report of the Education Commission (1990: p.100), mixed code teaching in English-medium schools may impede students' cognitive development. Valuable lesson time is being wasted on translation of English texts in class and learning is often reduced to rote memorization of facts in English. When a teacher uses mixed code in teaching, students tend to pay more attention to instruction presented in Chinese, and switch off when instruction is in English. This practice is therefore at odds with the purpose of immersion which aims at providing students with the opportunity and motivation for learning English through content subjects.

Some educators (e.g. Luke, 1992; Johnson, 1997; Rollnick, 2000) have argued that mixed code teaching is a coping strategy to resolve the problems of covering a heavily loaded curriculum and unselected EMI students. Many EMI students have comprehension difficulties with instruction in English (Chapter 1, p.5). Some teachers, particularly those teaching mathematics and science, are also limited by their own language competence, and are unable to express themselves accurately and fluently in English (Ip and Chan, 1985; Johnson *et al.*, 1991). By explaining subject content in Cantonese, teachers believed that their students could gain a better understanding of the curriculum materials that were written in English. Furthermore, interaction between the teacher and students would be more active and extensive when Cantonese was used for instruction. The result of this kind of practice was, however, highly unsatisfactory as the weaker EMI students could not achieve the intended high levels of English proficiency through such mode of immersion, while their interest and chance of success in learning subject knowledge was seriously jeopardised. A similar situation is observed in the Philippines in which English, as a second language, is used for instruction of science and mathematics. Code switching between Filipino and English is common during lessons, even in the high schools and colleges (Gonzalez and Sibayan, 1998). The prevalence of this practice has been attributed to the low English proficiency of both the students and teachers.

Given that mixed code teaching has negative effects on the development of L2 proficiency through immersion, the limited success of the English immersion programme in Hong Kong is more likely to be attributed to the non-selection of students for English-medium instruction. The Education Commission (1990) concludes that students with inadequate English proficiency would have greater difficulty in understanding instruction in English and they would be disadvantaged in academic achievement. Accordingly, it recommends that EMI should be restricted to schools that recruit students that have reached a certain threshold of language competence in both their mother tongue and English (Education Commission, 1990: p.94). These considerations lead to the establishment of a selection process in the *Guidance* (Education Department, 1997) that identifies EMI-stream students as those who are academically capable of learning effectively through English (Chapter 1, p.14). The *Guidance* also discourages the use of mixed code in teaching. This measure is intended to promote more student-teacher interaction in English during class, thus making full use of immersion in developing second language skills.

PART II:

1. LITERATURE REVIEW ON THE EFFECTS OF MOI ON ACADEMIC ACHIEVEMENT

If immersion results in children becoming proficient in L1 and L2, the question is whether this is at the cost of achievement in content subjects. The present study addresses this issue of MOI on science learning. It seeks to explore the effects of the late immersion approach advocated in the *Guidance* on science learning of the EMI students in Hong Kong, as compared to that on the CMI students. Although a considerable amount of research has been done on immersion programmes, most of these studies have been focused on the development of students' language abilities, in both L1 and L2, and only a small number are concerned with the learning of content subjects. Among the studies that explore the effects of MOI on content subjects, the findings are inconclusive and sometimes contradictory. A review of these studies can provide a useful background for understanding the possible impact of the new language policy of Hong Kong on science learning of the EMI students.

French immersion programmes in Canada

In Ontario and elsewhere in Canada, a key concern of parents and educators about immersion education was whether immersion students would be able to keep up with their English-medium peers in content subjects taught to them in French. To address this concern, a number of standardised tests on mathematics achievement were conducted on immersion and non-immersion students. Analyses of covariance, with IQ as the covariate, were carried out in order to compare the achievement of students of these two groups in mathematics. In a few cases, the English-taught, non-immersion students scored significantly higher than the immersion students, but in some other cases, the immersion students demonstrated better performance on the mathematics test. Despite these variations, the results of most studies (e.g. Edwards *et al.*, 1979; Genesee, 1987; Swain and Lapkin, 1982) show that there are no statistically significant differences between the mathematics achievement of the two student groups, indicating that the immersion students were not at a disadvantage by receiving instruction in French.

In most of the standardised science achievement tests administered to grades 5 to 8 in Canada, the average scores of the immersion students and their English-taught peers are equivalent (Cummins and Swain, 1986; Genesee, 1987). These results indicate that science achievement of students is neither positively nor negatively affected by receiving instruction in the second language. Genesee (1976, 1977) reported that one-year late immersion students scored as well as their English control peers on science tests, after controlling the student samples for IQ using analysis of covariance procedures. Swain

(1978) reported that early total immersion students in Ontario scored as well as the non-immersion students on standardised science tests. However, late immersion students were found to score significantly lower than the English-programme students at the end of the first year of the programme, but they caught up by the end of the second year. These students started the immersion programme at grade 8, and studied French language as a subject in grade 7, just one year before immersion. A possible interpretation of the lag in science achievement of the immersion students at the end of year 8 is that their second language skills were interfering with the learning of subject matter. This explanation is supported by the subsequent observation that there was no difference in achievement in science, mathematics, geography and history between the French-immersion and English-programme students at grades 9 and 10.

These findings on the effects of immersion on academic achievement, however, must be treated with caution for a number of reasons. Some of the results (e.g. Andrew *et al.*, 1979; Swain and Barik, 1977) are based on a small number of classes, and so the findings could vary according to class-specific factors. The content of standardised tests are not specific to the curriculum of the schools studied. Moreover, these results are often based on the performance of earlier grades, and the long-term effects of immersion have not been adequately assessed. In order to obtain results that can be generalised to a wider context, it would be preferable to conduct achievement tests constructed according to the curriculum of the schools concerned on a larger number of immersion classes for a longer period of years.

English immersion in African countries

It has been reviewed in a previous section (p.29) that in many African countries, after shifting from early immersion to late immersion, children are able to develop proficiency in both L1 and L2. This section reviews the studies on the effects of MOI on the learning of content subjects in some African countries.

In Cameroon, most schools use the official language, either English or French, for instruction starting from the primary level. This is a foreign language for most students. Gfeller and Robinson (1998) report the results of a language-teaching project initiated 1980s to compare the effects of teaching young children through their mother tongues or through a foreign language. For the first three years of the primary school curriculum, students in the experimental schools were taught basic knowledge, including reading, writing and arithmetic, through their native language. At the same time, the official language was taught as a school subject. From the fourth year onwards, the official language became the language of instruction, although the native language was still used for the teaching of some subjects such as local culture, history and geography. When the experimental classes were compared with the control classes at the end of the first year, their performance in French, the official language, was the same as the control classes. However, the students of the experimental group were found to perform slightly better in arithmetic than students of the control group. In addition, they had learned their own native language. These students also showed preference in learning through their own language rather than through the official language because they could express themselves with more facility. In contrast to the Canadian findings, these results suggest that early immersion may have negative effects on the learning of content subjects such as mathematics, probably because the children are still not proficient in L2.

In the secondary schools of Malawi, English is the medium of instruction although the native language of most students and teachers is Chichewa. Reinhard (1996) reports a study which evaluated the effects of MOI on science learning. Two Form 3 (aged 17-18 years) classes in a secondary school were taught electrochemistry in different languages, one through English and the other through Chichewa. The performance of the Chichewa-medium class on the pre-test was better than that of the English-medium class, but the difference was not significant. The results of the posttest showed improvement in both classes, indicating that learning had occurred. The performance of the Chichewa-medium group was, however, slightly lower than that of the English-medium group. This result tends to suggest that learning through a foreign language, such as English in this case, has no adverse effect on the learning of science when compared with learning through the students' mother tongue. One reason put forward by Reinhard to explain the lower performance of the Chichewa-medium group in her study is that the students might lack adequate terms in Chichewa to express their scientific ideas. Another possible reason is the short duration of the study, which lasted for five periods only. There was not enough time for the students to gain confidence to use Chichewa as a medium to communicate scientific ideas. This interpretation is supported by the results of a similar study (Kachaso, 1988) that involved a longer period. In this study, 25 periods were used for teaching grade 7 mathematics using Chichewa or English. Students instructed in Chichewa were found to score significantly higher in the post-test than those instructed in English. This and other studies (e.g. Collison, 1975; Ehindero, 1980) lead to the conclusion that learning in the vernacular language improves achievement in content subjects including science.

Partial immersion in the Philippines

The language situation in the Philippines is multilingual in nature. Vernacular languages for communication are used at home and in the neigbourhood, Filipino is the national language, and English is used as the language for academic discourse and business. Since 1974, an early partial immersion model has been used throughout the six years of primary education and four years of secondary education, with Filipino and English as the main media of instruction. Filipino is used for most subjects which are mainly related to social studies while English, the second language, is used for instruction on science and mathematics. In reality, code switching between Filipino and English is common in science and mathematics lessons, even in the high schools and colleges (Gonzalez, 1998).

In 1994, national tests were developed to evaluate the immersion programme by measuring student achievement in language and subject matter at the end of Grade 6 and the last year of secondary education (Grade 10) (Gonzalez, 1998). Teachers were also assessed using the same tests to find out the correlation between the student results and those of their teachers. Instead of setting national standards, the test results enable individual schools to compare the attainment of their students with that of others within the same district. Each test assesses a number of set targets according to the national curriculum, and a score indicating achievement of 50% of the set targets is considered to reach a 'pass' level.

Item analysis of these national tests by Ibe and Coronel (1995) showed that students' achievements were lower than expected, especially in higher order cognitive skills, critical thinking and conceptual understanding with word problems in mathematics. In general, students scored higher in Filipino than in English in the language tests. Many teachers, administrators and parents attributed the poor achievement in English to the relative small amount of time allocated to English instruction in the immersion scheme. It was expected that the use of Filipino would improve the learning of content in social studies, but the average scores in this subject were 50%, meaning that the schools had only achieved an average of about 50% of the set targets. For subjects taught in English, the performance was also considered unsatisfactory, with averages of 50% in mathematics and 40% in science. Socioeconomic status of the schools, their physical surroundings and locations, and laboratory equipment, library facilities, qualifications and effectiveness of teachers were found to be good predictors of high test scores. Quality schools, with good management, strong logistic support, and qualified and effective teachers, yielded good results in all subject tested. These observations suggest that various home, teacher, school and community variables may interact to make immersion education more or less effective.

The overall achievement of the teachers in the tests was low, with an average of about 50% in the subjects they were teaching. The results in physics were particularly poor, averaging only 40%. A team of evaluators visited and examined the schools for effectiveness. It was found that schools evaluated low on the criteria for school effectiveness yielded poor student results, and there was a high correlation between student achievement and teachers' level of proficiency in subject areas (Gonzalez and Sibayan, 1988). While the poorer performance in science had been attributed to the inadequate subject knowledge of the science teachers, the result also suggests that science learning was hindered by the low English proficiency of the students and teachers. English belongs to a language family totally different from Filipino. Moreover, competence in English is closely related to socioeconomic status, since children of the poorer classes, due to poor teaching and living conditions, are seldom functionally literate in English. This has an adverse effect on their ability to carry out higher cognitive activities that are required for the effective learning of science (Gonzalez, 1998).

*Immersion programmes in the U.S.*A

Foreign language immersion programmes in elementary schools in the United States have grown significantly since the early 1970s. Most immersion programmes involve Spanish, as there are a large number of Spanish-speaking immigrants from Central and South America, but there are also programmes in French, German, Japanese and Chinese.

These programmes are mainly early total immersion or early partial immersion, in which only half of the school day is spent in the immersion language. According to Met and Lorenz (1997), teachers involved in partial immersion programmes reported that their students could handle concrete objectives in the immersion language in the primary grades, but were frustrated in the learning of abstract concepts in higher grades, probably because their cognitive development was at a level higher than their language proficiency. To facilitate learning in higher grades, some teachers used English when dealing with abstract concepts, or allowed their students to communicate in English. These observations point to the need for matching the cognitive demand of the subject curriculum with the L2 language ability of the students in order to achieve desirable effects of immersion. The same problem is also observed in Hong Kong. When dealing with more abstract or complex concepts in content subjects at the senior secondary levels, many EMI teachers tend to use a mixed code of Chinese and English to enhance student understanding, because they believe that the English proficiency of many students are not sufficiently developed to enable them to think abstractly in their second language.

Meta-analysis is a statistical procedure that can assess the effect of variations in programmes. Using this technique, Willig (1985) compared the bilingual programmes conducted in American schools with traditional programmes, in which non-native English-speaking students were taught exclusively in English. After controlling prior student differences, minority language students who were taught in their native language performed significantly better than the English-taught peers throughout the curriculum, such as in reading, language, mathematics and overall achievement. The bilingual students also showed more positive attitudes towards self and the school. However, such programmes are significantly different from the immersion models implemented in Hong Kong and other places, as they aim at protecting and developing children's native languages alongside the development in the majority language. They also aim at fulfilling an important function of building ethnic identity in the children in a majority language society (Fishman, 1989).

Although not one single study in this meta-analysis included science achievement, these findings suggest that children can learn more effectively in their mother tongue than in a second language in certain contexts. A criticism of Willig's meta-analysis is that it only included 23 studies, which showed great variation in the nature of students, the social and cultural ethos of the programme, and the variety of language intake within the programmes. For example, some programmes start with children at a similar level of language skills. In other programmes, the children start at different language abilities, making classroom teaching more difficult. Such variations make simple generalization difficult and unreliable.

English immersion in Hong Kong

In Chapter 1 (p.2 and 4) and elsewhere in this chapter, it has been pointed out that before 1998, due to the high parental preference for English-medium education, most secondary schools in Hong Kong opted for EMI without considering whether the English proficiency of their students was adequate for learning the content subjects or not. This situation has created serious learning problems in students with low English proficiency, particularly on the learning of science. Thus the issue of how the medium of instruction may affect the learning of content subjects is an important area of research in Hong Kong.

In a large-scale study involving 9095 secondary school students in Hong Kong, Siu and his co-workers (1979) investigated the effects of the language of instruction on student learning and cognitive development. Besides the medium of instruction, other variables such as students' intellectual ability and linguistic competence were also taken into consideration. Four lessons each of Mathematics, Science and World History were designed and taught to S2 to S4 (13 to 15 years old) classes in either English or Chinese. Data on the achievement of subject matter, Chinese and English proficiency levels, intellectual ability and classroom interaction were collected and analysed. According to Siu and his co-workers (1979), the use of CMI facilitated intellectual development and the CMI students generally learned subject matter more effectively than the EMI students. Thus it seemed that English was not an effective medium for junior secondary levels. However, the medium of instruction did not seem to cause any significant difference in the acquisition of subject knowledge for the high ability students or among the low ability students. The validity of these conclusions is, however, questionable because the fundamental assumptions underlying the study were unjustified. The students in this study were not in fact learning consistently through either language. In the English-medium classrooms in particular, the students were normally studying through mixed code. Furthermore, the conclusions drawn on an experimental situation of learning in Chinese or English for only four lessons are invalid for implying on the long-term effects of MOI. Drawing on similar studies, research on the Canadian immersion programmes, for example, has shown that immersion students require from five to seven years to catch up with the non-immersion students in achievement in first language and in content subjects (Cummins and Swain, 1986; Genesee, 1987).

In a 1991 study (Lo, 1991), standardised tests were used to assess achievement in Chinese, English and mathematics. The mean achievement scores of 2638 S3 students (14 year olds) in each subject were compared according to the MOI used in lessons. Students using Chinese instruction showed higher achievement in mathematics than those receiving either English instruction or a mixed code of Chinese and English. However, there was no significant difference in mathematics achievement between the students instructed in English and those instructed in the mixed code. One interpretation of these findings is that Chinese medium instruction facilitates mathematics learning because students and teachers can communicate and interact more effectively in Chinese than in English during lessons. It is thus inferred that Chinese-medium instruction would have even greater positive effects on the learning on other non-language subjects which are more verbal and less symbolic and figural in nature.

An unexpected result from this study is that students receiving instruction in mixed code demonstrated greater achievement in English than those receiving instruction in

English. A number of reasons have been proposed to account for the positive effect of mixed code instruction relative to instruction in English. For instance, the S3 students might not have reached the required level of English proficiency for them to be benefited from instruction in English, or the teachers might lack the English competence required for effective instruction in English. Based on his findings, Lo (1991) proposes that it is not advisable to abolish mixed code instruction in learning content subjects, and that well-planned language teaching is more effective than immersion in promoting the development of competence in English for secondary students, including those with high ability. The conclusions from this study should, however, again be viewed with caution because the sample sizes of the different groups are not comparable and the comparisons were make without controlling students' initial differences in academic ability. Furthermore, the validity and reliability of the achievement tests for Chinese, English and mathematics, which are constructed and administered by the Education Department, had not been testified.

In a recent study involving over 12,000 secondary students in Hong Kong schools, Marsh *et al.* (2000) traced the achievement of native Chinese-speaking students in EMI and CMI schools in language subjects and content subjects for three years starting from S1 (12 years old). While the CMI schools basically used Cantonese for teaching, the medium of instruction in the EMI schools might vary greatly according to the abilities of students. For many EMI schools with less able students, the teachers might use mainly Cantonese or a mixed code of Cantonese and English for teaching content subjects, though the textbooks and the examinations were in English. Prior student achievement was based on a placement score that represents an aggregate of achievement of a student in all academic subjects at the end of primary schooling that is moderated by external examinations. In each of the three years following entry into secondary school, the Education Department administered standardised achievement tests in English, Chinese, mathematics, science, geography and history. The achievement tests were administered to all students near the end of the school year (May to June) in the language of instruction in which the student studied the particular subject.

Marsh *et al.* (2000) report the findings as follows: After controlling for students' prior ability and other factors, comparison of students' achievement indicates that instruction in English had positive effects on English proficiency and, to a smaller extent, Chinese proficiency. However, the effects of English-medium instruction were negative on all other subjects, being relatively small for mathematics and greater for history, geography and science. The positive effects of English instruction on English and Chinese achievement were expected. These results support the parental belief that immersion in English promotes the development of both English and Chinese. However, a possible reason for the strong negative effects of English instruction on history, geography and science is that these three subjects are new content areas for secondary students. Learning these subjects in a second language is particularly demanding for students as they have to master the basic terminology as well as develop conceptual understanding of the subject matter and comprehend the textbooks in English. The results also suggest that the English language skills of the EMI students might be insufficiently developed to cope with the complex curriculum materials in these content subjects. These problems are less serious with mathematics, as mathematics learning involves the use of symbolic terminology that may not be so dependent on the language of instruction. For history, geography and science, the negative effects associated with instruction in English were the same irrespective of the students' initial academic ability. However, students who are initially more proficient in English are less disadvantaged by instruction in English (Marsh *et al.*, 2000).

A problem with the design of the study of Marsh and his co-workers that may affect the validity of data interpretation is that many of the so-called English-medium schools used Cantonese or mixed code for instruction, and only a small number of the EMI schools were truly English-medium. Given that in Marsh's study, most EMI schools were in fact mixed code, then in order to find out the effects of English-medium instruction on the learning of content subjects and to identify the optimum conditions for effective English immersion, it is necessary to analyse student achievements in these two types of EMI schools (English only or mixed code) separately.

However, the findings of Marsh's study suggest criteria for identifying students who would benefit from English immersion. The negative effects of instruction in English will be minimised if selection of students into EMI schools is based on prior English ability. Assigning schools into CMI and EMI streams according to the MIGA of S1 entrants, as stipulated in the *Guidance*, is in line with this principle as MIGA is a measure of the general academic and language abilities of the students (Chapter 1, p.14). As for schools using Chinese as MOI for S1 to S3, they may switch to English medium for certain subjects in some classes at S4 and S5, if their students become sufficiently proficient in English for the switch into English immersion (Education Department, 1997: p.8).

To study the impact of the implementation of the *Guidance* on the science learning of EMI and CMI students with time, the present study will compare the science achievement of these two streams of students in the first three years of secondary schooling. According to the findings of the Canadian research, it is expected that the negative effects of English-medium instruction on science learning will diminish with time, as the EMI students acquire better English language skills through immersion.

Implications for the present study

A number of conclusions can be drawn from the above literature review with respect to the academic outcomes of immersion programmes. These can inform the present study which is designed to study the effects of the *Guidance* on the science learning of EMI students.

The immersion model for Hong Kong schools as stipulated by the *Guidance* is quite similar to the late total immersion programmes of Canada. Based on the Canadian findings, it can be anticipated that the EMI students of Hong Kong may lag behind their CMI counterparts in science achievement in the early years of immersion. With the provision of favourable factors, such as effective teaching techniques, high student motivation, parental support and a well-designed curriculum, the EMI students are likely to "catch up" in later years as their English proficiency increases. Given that Chinese and English belong to two completely different language systems, the EMI students in Hong Kong may take longer time than the Canadian French immersion students to achieve at a level equivalent to that of their CMI peers.

Studies on early immersion programmes in some African countries indicate that children learning in their native languages show better achievement in content subjects than those learning in a second language. These results are different from those obtained from the Canadian immersion studies which show that early immersion in French has no negative effects on academic achievement. A possible explanation for this discrepancy is that early immersion in a second language may have negative effects on learning if L1 is linguistically different from L2 (Bunyi, 1999; Collison, 1975; Ehindero, 1980). This argument provides support for the rationale of adopting a late immersion model in the Hong Kong education system. By using Chinese as the medium of instruction and teaching English as a language subject in the primary school years, school children in Hong Kong are provided with the opportunity to develop basic Chinese language skills and content knowledge in their mother tongue, which can facilitate the switch in the medium of instruction in subsequent years. The mastery of basic literacy skills in Chinese by primary school students also helps them to establish a national and cultural identity before embarking on the immersion programme in the secondary schools.

In the Philippines and the EMI schools of Hong Kong before 1998, code switching is a prevalent in the classroom. The use of code switching has been attributed to the limited L2 proficiency of the students and sometimes of the teachers. With the implementation of the language policy of the *Guidance* in 1998, English-medium instruction is restricted to secondary schools that recruit students with appropriate L2 abilities and code switching is strongly discouraged. The present study will explore whether such guidelines will reduce the negative effects of science learning through a second language. Besides the language proficiency of the students and teachers, the Philippine studies indicate that the success of an immersion programme depends on other factors as well, such as home background, school support, and the quality of teachers. The effects of some of these factors will also be explored in the present study.

PART II:

2. LITERATURE REVIEW ON STUDENTS' ACADEMIC SELF-CONCEPTS

Academic achievement and self-concept are important outcomes of the learning process. In addition to promoting academic success, many educational policy statements also consider the formation of positive self-concept as one of the most important goals of education (Brookover and Lezotte, 1979). For example, one of the fundamental aims of Hong Kong education is "*to build up a positive view of self and positive values for life in pupils* ... and *due emphasis will be given by schools to the development of personal and ethical values in pupils* ..." (Board of Education, 1997: p.28). As the present study is designed to investigate the effects of MOI on science learning, the learning outcomes should include the science achievement of students as well as their self-concept in science.

Research on student self-concept has mostly been concerned with studying the causal relationship between achievement and self-concept. According to Skaalvik and Hagtvet (1990) and Marsh (1993), there are four possible patterns of causation: (a) achievement affects self-concept (skill-development model), (b) self-concept affects achievement (self-enhancement model), (c) achievement and self-concept affect each other (reciprocal effects model), and (d) external variables affect both achievement and self-concept. The question of causal relations has important implications on whether instruction and learning experience should focus on developing achievement or self-concept of students.

After reviewing a large number of studies, Marsh (1993) suggests that academic achievement is substantially related to academic self-concept but not to global components of self-concept. This is understandable as in the process of forming academic self-concepts, students must evaluate their academic achievements in relation to frames of reference. Furthermore, the academic self-concepts of different subjects are distinct from each other. For example, mathematics achievement is highly correlated with mathematics self-concept but not with English self-concept, whereas English achievement is correlated with English self-concept but not with mathematics self-concept (Marsh *et al.*, 1988; Marsh, 1993). Similar relations are observed in a longitudinal study with Hong Kong secondary students that involves the juxtaposition of self-concepts in native and nonnative languages, and mathematics (Marsh *et al.*, 2001). The results of this study support previous findings that the achievements in different subject areas, in this case Chinese, English and mathematics, have positive effects on the self-concepts in corresponding subject areas, but negative effects on the self-concepts in non-matching subject areas. Furthermore, these effects are very stable over time.

In an evaluation of structural equation models (SEM) of academic achievement, academic self-concept and global esteem for two cohorts of students on two occasions separated by 18 months, Skaalvik and Hagtvet (1990) showed that prior academic achievement had a significant effect on subsequent academic self-concept. Similar longitudinal studies (e.g. Helmke and van Aken, 1995; Muijs, 1997) also revealed that academic achievement predominated over academic self-concept during the elementary school years. Byre (1998) also found that general academic and mathematics achievement affected self-concept among high school students. These findings provide support for the skill-development model. Another finding from Skaalvik and Hagtvet's study (1990) is that there was a significant effect of prior self-concept on subsequent achievement for the older cohort, but no such effect was found for the younger cohort. The age differences of the effects of self-concept on academic achievement suggest that initial self-concept formation takes time and is dependent on academic achievement. Skaalvik and Hagtvet's study therefore provides evidence for the reciprocal effects between achievement and self-concept, in that initial achievement affects self-concept, and self-concept affects subsequent achievement. This reciprocal effects model is supported by the results of research studies that measured mathematics self-concept and achievement in German classrooms (Helmke, 1987; Helmke and van Aken, 1995). However, other studies showed either a reciprocal relation between academic achievement and self-concept (Marsh and Yeung, 1997) or a predominance of self-concept over achievement (Marsh, 1990a) for high school students.

To explain these apparently inconsistent results, Skaalvik and Hagtvet (1990) propose that the relation between achievement and self-concept undergoes developmental changes with time. They suggest that in early school years, a student's academic self-concept has not yet been established. During this period, academic experience will shape the formation of self-concept. As academic self-concept becomes better established and more stable, it may increasingly affect learning attitude and behaviour, which in turn may affect academic achievement. According to this reciprocal effects model, academic achievement and self-concept are reciprocally related and mutually reinforcing, i.e. improved academic achievement will lead to better academic self-concept and improved academic self-concept will in turn lead to better academic achievement.

Few research studies have examined the effects of the language of instruction on the development of academic self-concept in immersion programmes. According to a meta-analysis conducted by Willig (1985), students in bilingual programmes who were taught in their first language performed better on achievement tests and had better attitudes towards self and school. Consistent with this observation, Marsh *et al.* (2000)

found that in Hong Kong, immersion Chinese-speaking students learning through English showed lower academic achievement than their non-immersion peers in the first three years of secondary schooling. In another study, Marsh and Yeung (1997) showed that prior academic achievement affects subsequent academic self-concept, and that prior self-concept affects subsequent academic achievement. These findings on Hong Kong students support a model of reciprocal effects. Furthermore, immersion in English might also have negative effects on the formation of academic self-concept in Hong Kong students. Therefore, if lower academic self-concept may in turn lead to lower academic achievement, it is necessary to carry out further studies to confirm whether English immersion in Hong Kong secondary schools will have adverse effects on students' academic self-concept and, if such effects exist, to explore ways to improve students' academic self-concept.

This chapter has explored the issues of immersion education in Hong Kong, based on a critical review of the literature on the effectiveness of different immersion models in promoting L1 and L2 proficiency. It has also considered the effects of the medium of instruction on the learning of content subjects, including different aspects such as students' academic achievement and self-concept. The following chapter will present the research questions, conceptual framework and methodology for the current study, drawing on a number of findings and conclusions from research studies on immersion programmes that are relevant to the Hong Kong context.

CHAPTER 3

RESEARCH FRAMEWORK, PHILOSOPHICAL UNDERPINNING AND METHODOLOGY OF THE STUDY

AIM OF THE PRESENT STUDY

The present study is launched to investigate the effects of English immersion on science learning in the first three years of secondary schooling, as based on the immersion model stipulated in the *Guidance* (Education Department, 1997). In Chapter 2, related studies on the effects of immersion on linguistic and academic achievement have been reviewed. These studies are based on different immersion models, which are implemented in education systems of various nature in terms of culture, L2 proficiency of students and teachers, and the relatedness of language structure between L1 and L2. While the findings of these studies are sometimes inconsistent and may be open to different interpretation according to the contexts involved, it is useful to summarise some of these findings that are relevant to the research questions to be formulated in the present study:

1. *Immersion students tend to achieve higher levels of proficiency in L2 than non-immersion students* (p.24, 27). This is the main purpose of adopting an English immersion programme in the EMI schools of Hong Kong.
2. *Proficiency in L1 will facilitate the development of L2* (p.24). This points to a need for students to acquire L1 competence before immersion in L2, particularly when L1 and L2 belong to different language systems. Can the late immersion model of Hong

Kong, with English immersion starting in secondary schools, ensure that the immersion students have gained adequate Chinese language skills during their primary schooling?

3. *Effective learning through L2 is dependent on high-quality pedagogical interactions* (p.27, 48) *and adequate L2 proficiency of students and teachers* (p.30, 48). Do the selection criteria for EMI students stipulated in the *Guidance* ensure the EMI students learn effectively through English? Do the EMI teachers possess the skills for promoting pedagogical interactions through L2?
4. *Mixed code teaching tends to reduce students' opportunity and motivation for learning L2 through content subjects* (p.38, 49). The *Guidance* discourages the use of mixed code teaching in the EMI schools. Does this practice facilitate or impede science learning through English?
5. *Late immersions students do not suffer long-term negative effects in learning content subjects in comparison with non-immersion students* (p.42). Can this finding of the Canadian immersion programmes be generalized to the Hong Kong context? For how long will the EMI students of Hong Kong lag behind their CMI peers in academic achievement before catching up?
6. *In the early secondary years of Hong Kong, English Immersion has negative effects on academic achievement which may affect the formation of academic self-concept* (p.62). This implication about the effects of English immersion on academic self-concept development has to be substantiated by further studies.

The rationale of the language policy underlined in the *Guidance* is in general consistent with the above findings. The designation of most secondary schools into the CMI stream and a small number of schools, which take in the most able students, into the EMI stream was based on the following principles:

- Children learn best in their mother tongue.
- Learning through English, which is a second language to the Chinese students, can be effective only when the students have reached an adequate level of English proficiency.
- Mixed code teaching is not effective, hence the requirement for EMI schools to observe strictly the language of instruction in order to prevent the practice of teaching in Cantonese or mixed code in these schools.
- EMI students will be given the full opportunity and motivation to develop and use English language skills through learning the curriculum materials in content subjects without recourse to Cantonese.

The aim then of the new language policy is to provide students of different language competences and academic capabilities an optimal learning environment for effective learning.

In order to explore the impact and implications of this language policy, the Education Department commissioned the Faculty of Education of the Chinese University of Hong Kong to conduct a research project to study the effects of the MOI policy on the achievement of EMI and CMI students in Chinese, English, Mathematics, Social Studies and Science. The present study is part of this research project that focuses on the effects of late immersion on science learning. It will study the science learning of the EMI students, as compared with that of the CMI students, in schools that have implemented the new language policy in their first three years of secondary schooling.

RESEARCH QUESTIONS OF THE PRESENT STUDY

The overarching aim of the present study is to investigate the effects of language of instruction on science learning of EMI and CMI students in Hong Kong, after implementing the language policy of the *Guidance* in 1998. This is a longitudinal study on a cohort of students from S1 to S3. Science learning can be assessed by its outcomes, which are mainly concerned with the achievement and self-concept in science. The study is guided by the formulation of the following research questions:

1. What are the effects of MOI on the science achievement of secondary students?
2. What are the effects of MOI on students' self-concept in science?

The first research question can be further conceptualised as made up of the following components:

(i) How do the EMI students differ from their CMI peers in science achievement?

(ii) How do the effects of MOI on science achievement change over time?

(iii) How are the effects of MOI on science achievement related to the instructional activities in science lessons?

PHILOSOPHICAL UNDERPINNING OF THE STUDY

The present study is an *ex post facto* research by design. Its primary aim is to explore retrospectively the effects of the medium of instruction, which is the independent variable, on the learning outcomes in science, the dependent variable, with a view to establish causal relationships between them (Kerlinger, 1970). As it is not possible to assign students randomly into the EMI or CMI stream, an inherent weakness of *ex post facto* research is lack of control on the independent variable (Spector, 1993). The researcher cannot manipulate the independent variable or randomize her subjects. This problem, however, can be resolved to some extent by using procedures that give the researcher some measure of control in her investigation. One way to do this is to match the subjects in the experimental and control groups. However, this method cannot be used in this study because the EMI students are basically selected for their higher academic achievement. A feasible alternative is to use statistical techniques that control the effects of extraneous factors when comparing the outcomes of science learning of the EMI and CMI students (p.84).

The present study adopts a quantitative approach for assessing the outcomes of science learning of students and the classroom climate in science lessons of different MOI streams, through the use of achievement tests and a student questionnaire. This is complemented by a qualitative study which attempts to examine the complexity of classroom climate from another standpoint, and to account for the effects of MOI on science learning by examining the instructional activities taking place in science lessons.

The following sections discuss the philosophy for planning the actual study, with a consideration on identification of the population and samples, the selection and construction of methods for collecting data, and the techniques for data analysis.

1. The quantitative study

Sampling process

The first step in planning a research is to define the population to be studied. Due to constraints in time, funding and accessibility, it is not practical to obtain data from the whole population. The researcher needs to collect data from a subset of the population in such a way that the information obtained is representative of the total population under study. The way to select a representative sample is dependent on the aim of the study.

The population upon which this study is to focus includes all Hong Kong students entering secondary schools in 1999. The quantitative study is based on a longitudinal sample of 100 secondary schools, which were selected by a stratified random sampling method. Two sets of strata are used in selecting the schools. To address the primary objective of the current study of finding the effects of MOI on science learning, the first stratum for sampling schools is the MOI streaming. 25 schools were randomly selected from the EMI schools, and 75 schools from the CMI schools. As for the CMI schools, they were selected on the basis of another stratum. The CMI schools were stratified into high, medium and low strata (i.e. CHIG, CMID and CLOW) according to the mean academic ability of their S1 intake, which is measured by the mean AAI (Academic

Aptitude Index) of their students. The AAI of a student is a score based on the student's academic performance in school-based examinations in the last two years of primary education, moderated by a public aptitude examination. Components of this score are also used for assigning students into different MIGA groupings (Chapter 1, p.14). Thus 25 schools were randomly selected from each stratum, resulting in a total of 75 CMI schools.

The reason for selecting the EMI schools using a simple random sampling method is that the EMI schools are relatively more homogeneous in their student intake. As for the CMI schools, the ability of their students is more heterogeneous. They were therefore stratified according to the ability of their student intake in the sampling process. This sample design would produce a representative sample of Hong Kong secondary school students in terms of academic ability. On the whole, the sampling rate is about 25%. Statistically, a sample of 100 schools is the minimal sample size because, for multi-level analysis which will be used in this study, a minimum of 25 second-level units (the schools) is required for valid analysis (Bryk and Raudenbush, 1992).

Using written tests to assess achievement in science

The first line of inquiry is to assess students' science achievement. This can be achieved by using a written test, such as a science achievement test set according to the learning objectives of the science curriculum of each level. The test items should be specifically linked to the science programmes implemented in the sampled schools and assess the relevant knowledge and skills. A combination of different question types can provide a comprehensive picture of students' achievement in science. For instance, multiple-choice items can assess objectively a wide range of knowledge and skills within a relatively short test time, while free-response questions can assess students' writing and organization skills as well as higher order cognitive abilities. These considerations provide the guidelines for constructing the science achievement tests used in this study.

Performance on an achievement test can inform us about the strengths or weaknesses of the subjects in certain content areas or cognitive skills, but it cannot tell us the underlying reasons for the differential performance. For example, a poor performance on items of higher cognitive demands cannot tell us whether the failure is due to lack of the cognitive skills, development of alternative concepts, or misunderstanding of the question due to limited language proficiency.

After the trial version of the test has been prepared, it should be pre-tested using subjects similar to those that will be involved in the actual study. Pre-testing provides the opportunity to check whether the subjects understand the meaning of the questions, and whether the test items are set at an appropriate level of difficulty (Converse and Presser, 1986). The structure and wording of the instrument is then revised so that it has satisfactory levels of reliability and validity.

Using the statistical technique of analysis of variance (ANOVA), the mean scores of science achievement tests between the EMI and CMI schools can be compared. The results will reveal whether EMI has any negative effects on science learning in comparison with CMI. Analysis of performance on individual items of the test provides more in-depth information on the relative strengths and weaknesses of students of different school strata. Multivariate analysis, such as multi-level analysis, is a useful statistical technique for exploring the hierarchical nature of educational settings (Raudenbush *et al.*, 2000). After controlling students' prior academic ability and other contextual factors such as students' gender and family background, multi-level analysis can show the extent to which differences in achievement depend on individual or school effect, and so isolate the relative contribution of the individual and the school to the learning outcome under consideration. This method provides a more accurate picture of the impact of the new language policy on science learning of secondary school students.

Using a questionnaire to assess students' self-concept and perception

The second line of inquiry is to explore students' self-concept in science. A common method for collecting data in this area is to use a questionnaire to survey students' perception of their ability and interest in science. The self-concept instrument designed and validated by Marsh and his collaborators (Marsh, 1993; Marsh and O'Neill, 1984; Marsh *et al.*, 1988) will be adapted for the current study. For the items used, the respondents are asked to indicate their views or preferences according to a Likert scale. The mean scores of different school strata obtained from the questionnaire can be treated with ANOVA to identify the effects of MOI on students' self-concept in science.

To explore how the MOI may have contributed to the differential science achievement and self-concept of students, it is necessary to study the classroom climate of science lessons in the EMI and CMI schools. This information can be collected through a student questionnaire on students' perception of instructional activities and learning atmosphere in science lessons. Items for the present study can be adapted from well validated instruments such as the Questionnaire on Teacher Interaction (Goh and Fraser, 1998) and the Teaching Practice Evaluation Guide (Yip, 2001). A Likert scale is also used for the subjects to indicate their perceptions.

A weakness with self-report data obtained from a questionnaire is that the perception of a respondent is often affected by personal experience and expectation, and external factors such as the peer's abilities and attitudes. There is also a problem of interpretation of the data as different respondents may hold different meanings for the same rating in a scale. Furthermore, respondents may not be willing to answer an item honestly, particularly when they feel threatened by a question that is concerned with personal problem or inadequacy.

These limitations should be borne in mind when dealing with data on students' self-concept and perception of classroom climate collected from a questionnaire. Such information should be triangulated with other methods of data collection, including qualitative methods. For example, the data on students' self-concept in science can be compared with the results of the science achievement tests; students' perception of classroom climate can be validated by information collected from classroom observations.

Despite these limitations, in a study that explores the effects of MOI on science learning, the views of the students who are directly affected by the policy will provide an important source of information for interpreting the differential learning outcomes in science for the EMI and CMI students.

2. The qualitative study

Data on students' perception of classroom climate in science lessons will provide preliminary information about the possible effects of the medium of instruction on the teaching styles of science teachers and the type of activities carried out in science lessons. To seek evidence of these effects, a qualitative study that involves the direct observation of classroom teaching of science teachers is conducted. Classroom observation of science lessons provides the opportunity to gather live data *in situ* rather than at second hand (Patton, 1990: p.203-205). This method allows the researcher to collect information about classroom activities beyond perception-based data, and to gain a better understanding of the instructional activities occurring in science lessons.

Though classroom observation has the merit of providing a more in-depth study of classroom climate for understanding the effects of MOI on science learning than quantitative study, a common criticism on the method of observation, as with qualitative research in general, is that the observer may tend to be subjective during data collection. The extent of subjectivity when using observation can be reduced by recording classroom interactions and instructional activities in a systematic manner. This can be achieved by developing clear criteria for assigning various classroom events into well-defined categories, so that different observers should arrive at similar descriptions of the same events (Rosenshine, 1970; Galton, 1997).

Various methods exist for recording classroom interactions and activities (Croll, 1986; Teddlie *et. al.*, 1989). These include event sampling (which records the frequency of an event), instantaneous time sampling (which records the occurrence of an event at a particular pre-set interval), scanning (which records the number of students engaging in a particular activity at pre-set intervals) and expert rating (which rates the occurrence of effective teaching attributes on a scale). For the present study, expert rating is considered to be more appropriate because the observation is focused on instructional activities and classroom interactions that are specific to science learning, and the data can be interpreted more easily. To use this method effectively, however, the observer needs to be experienced in coding the type of activities and interactions observed and expert in making judgment on the rating form. The lessons are videotaped to facilitate more in-depth analysis of the lessons at a later time or review of the lessons by different observers.

Due to constraint in time and manpower, the present study will focus on classroom observation for a small number of schools selected from the two MOI streams. Because of the small number of science lessons observed and only some teachers were willing to be observed, the science lessons observed may not be representative of the sampled schools. Nevertheless, it is hoped that some generic differences can be identified between the instructional activities observed in science lessons using different instruction media.

This information can substantiate the results on the science learning outcomes of the EMI and CMI schools and provide tentative explanations for the different effects of MOI on science learning.

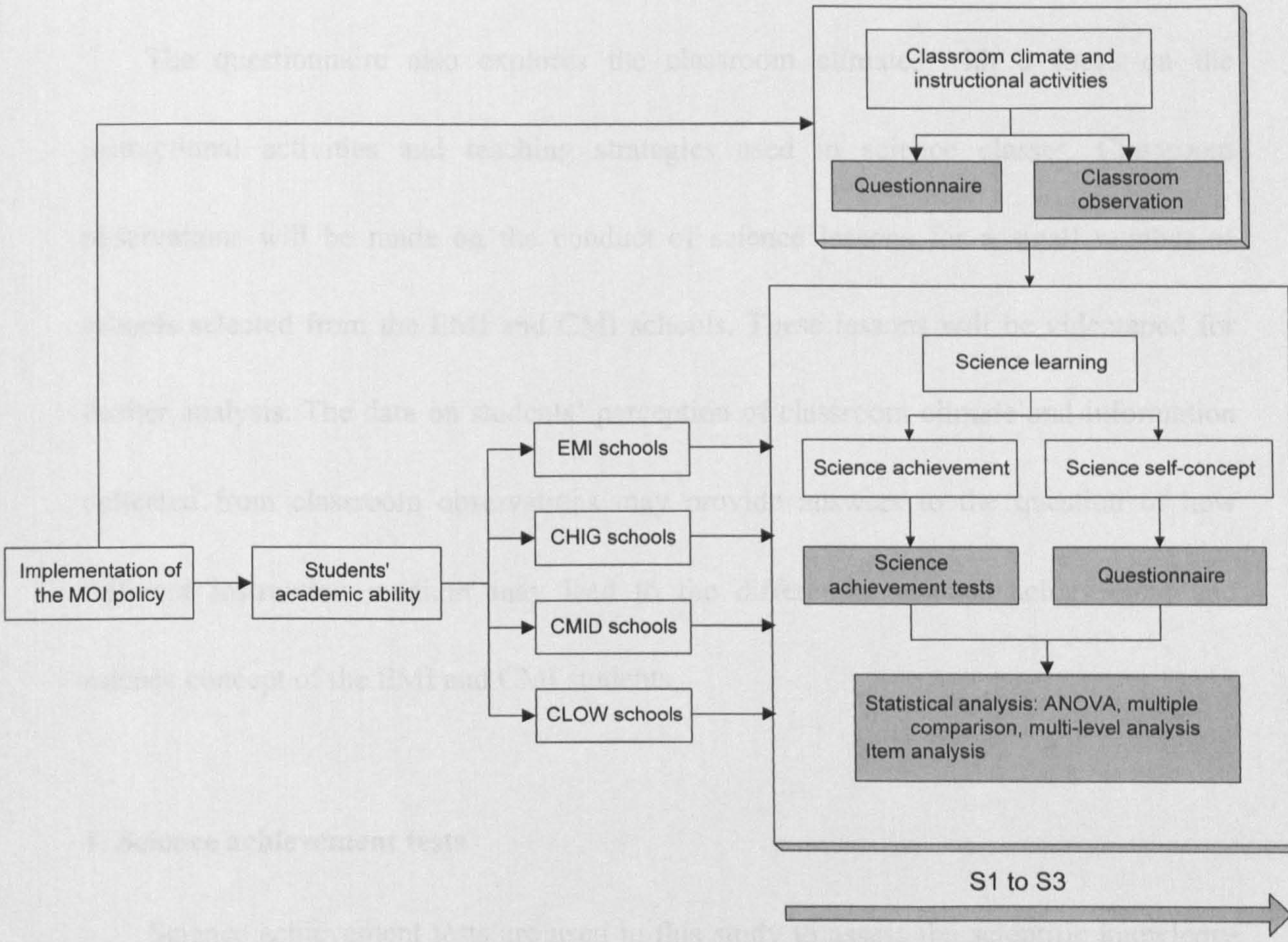
CONCEPTUAL FRAMEWORK OF THE STUDY

The formulation of the research questions and the philosophical consideration on how to answer these questions lead to the construction of a conceptual framework for this study. The conceptual framework (Figure 1) outlines the chronological and logical relationship of the following areas of inquiry:

- What is the treatment under study?
- How to sample the subjects for this study?
- What effects of the treatment will be measured?
- What methods will be used to measure the effects of treatment?
- How to analyse the results?
- What is the time frame of this study?

This framework guides the different stages of the study. In the next two sections, the Instruments and the Methodology of the present study presented in the framework will be described more specifically.

Figure 1 *Conceptual framework of the present study*



INSTRUMENTS USED IN THIS STUDY

Two aspects of student learning outcome are investigated in this study: the students' achievement and self-concept in science. Science achievement refers specifically to students' mastery of scientific knowledge and skills. It is based on the performance of the four different school strata on science achievement tests administered for three consecutive years starting from 1999-2000. Another important outcome of science learning is the development of self-concept in science. In this study, students' self-concept in science is assessed by a student questionnaire which elicit students' perceptions of their interest and competence in science.

The questionnaire also explores the classroom climate, with a focus on the instructional activities and teaching strategies used in science classes. Classroom observations will be made on the conduct of science lessons for a small number of schools selected from the EMI and CMI schools. These lessons will be videotaped for further analysis. The data on students' perception of classroom climate and information collected from classroom observations may provide answers to the question of how different instruction medium may lead to the differential science achievement and science concept of the EMI and CMI students.

1. Science achievement tests

Science achievement tests are used in this study to assess the scientific knowledge and skills of a large number of students. Three science achievement tests have been constructed, one for each level from S1 to S3 (Appendices 1-3). They are based on the science curriculum to be covered in each year. Each test consists of multiple-choice items and a small number of free-response questions. These items test scientific knowledge and skills prescribed in the science curriculum, and assess both low and high order cognitive skills. Although all schools follow the official science curriculum, there is always some variation in the curriculum content covered by the participating schools by the time of testing. This variation may be due to different speeds of teaching of the schools or curriculum tailoring by some schools. This variation may affect the validity of the tests as a measure of science achievement of students in different MOI streams. Such variation is particularly great in S3 since some schools may use part of the curriculum time to teach certain S4-5 science topics in lieu of some S3 topics.

The multiple-choice items are machine-marked while the free-response items in each test are marked by a team of 3-4 markers. The markers are science teachers with a university degree in science. They are trained by the author in using the marking scheme for marking the free-response items. Consistency in marking is ensured by regular check-marking by the author during the marking period.

2. Student questionnaire

This study uses a questionnaire of 16 items (Appendix 4) to assess students' self-concept in science and their perception of instructional activities in science lessons when the subjects were in S2. Each item is rated on a 4-point Likert scale. A questionnaire with rating scale is used here because it takes little time to fill in and is easy to administered. Furthermore, the data collected can be subjected to statistical analysis readily.

The 7 items on science self-concept are adapted from a well validated instrument for assessing academic self-concepts (Marsh, 1990b; Marsh and O'Neill, 1984). The 9 items on instructional activities are constructed by science educators of the Faculty of Education of the Chinese University of Hong Kong, with reference to some validated instruments (p.72). The questionnaire has been piloted on a similar student cohort a year before its administration to the 99-cohort of students in S2. Due to time constraints for completing the questionnaire and achievement test, the questionnaire contains a relatively small number of items, which may limit the scope of data that can be collected. Another limitation with the use of a rating-scale questionnaire is the problem of interpretation – a particular rating, such as 'agree' or 'strongly agree' and 'rarely' or 'sometimes', may not have the same weighting by different respondents, and the researcher cannot probe the respondents to find out what they mean by particular responses. As different people may have different frames of reference when making their perception-based rating, there is bound to be some degree of subjectivity on the data collected with this method.

3. Classroom observation form

Structured classroom observation is conducted in this study. The instrument for evaluating the science lessons is an inventory of 18 items adapted from the Teaching Practice Evaluation Guide (TPEG). The original TPEG is a 48-item instrument used for assessing a teacher's performance in various areas of teaching, such as lesson planning, teaching approach, development of the lesson, questioning skills, quality of explanation, communication skills and classroom management (Yip, 2001). It has been developed and validated by the science educators of the Department of Curriculum and Instruction of the Chinese University of Hong Kong. In the present study, the specific purpose of classroom observation is to compare the instructional activities taking place in the science lessons of EMI and CMI schools. To achieve this purpose, classroom observation in the present study will only focus on the teaching style and mode of interaction in science lessons. The instrument used is a form called the Science Lesson Evaluation Guide (Appendix 5). This guide is made up of 18 items adapted from the TPEG focusing on (a) Teaching style, (b) Questioning skills and (c) Communication skills. The author or his colleague will use this form to assess the teaching skills of science teachers inside the classroom or laboratory, or when playing back the videotaped lessons.

The findings from classroom observations will be useful in validating the differences in students' perception of instructional activities in science lessons between EMI and CMI schools, and exploring the underlying causes for such differences.

METHODOLOGY

Having described the research framework and the instruments used in this study, the following sets out the specific methodology of the present study. This includes the sampling of the subjects, the conduct of the science achievement tests, the methods for analysing the test performance, the administration of the student questionnaire on science self-concept and classroom climate, and the conduct of classroom observations.

1. The subjects

This study tracks the science achievement of a cohort of students who entered S1 (12 years old) in September 1999 for three consecutive years. As the new MOI policy was first implemented in 1998, the 99-Cohort is the second group of students affected by the new language policy stipulated by the *Guidance*. For this study, 100 secondary schools were sampled by the stratified random sampling method. 25 schools were randomly selected from the 114 EMI schools. The CMI schools are divided into high-, medium- and low-ability strata (CHIG, CMID and CLOW) according to the mean AAI (Academic Aptitude Index) scores of their S1 student intake (p.68-69). This sampling design ensures that the study will cover a representative sample of junior secondary school students in terms of academic ability.

The mean AAI of the students in the four strata show that the S1 students of these four strata fall into four distinct levels of abilities, being highest in the EMI stratum and lowest in the CLOW stratum. The difference between the AAI means of any two succeeding strata is significant at the 0.001 level for all cases (Table 1).

Table 1 *Mean AAI of different strata of the 99-Cohort and the difference between the means*

		EMI	CHIG	CMID	CLOW
N		4716	4614	4347	3939
Mean		115.81	108.45	99.07	83.66
Standard error		0.15	0.15	0.16	0.16
Difference of the means	EMI	-	7.35*	16.73*	32.15*
	CHIG	-	-	9.38*	24.80*
	CMID	-	-	-	15.42*

* The difference of the means is significant at the 0.001 level.

2. The Science Achievement Tests

An important measure of the effectiveness of science learning is students' achievement in scientific knowledge and skills. The science achievement of the

99-Cohort students was assessed by a written test near the end of each academic year (i.e. from April to July) in S1, S2 and S3. Each Science Achievement Test consists of two parts (Appendices 1-3). Part A contains 22-30 multiple-choice questions, each with four options. This part assesses students' knowledge and understanding in subject matter covered in the science curriculum of that particular year (CDC, 1986). Part B contains three free-response questions with a total score of 9 marks. For the questions of this part, students are required to organize their ideas and present them accurately and concisely. This means that these questions assess students' communicative skills as well as their knowledge and understanding in science.

The CMI students worked on the Chinese version of the achievement tests. However, two versions of the test paper had been prepared for the EMI students, in order to study the impact of language on their understanding or interpretation of written questions. Most EMI students were tested with a bilingual paper, with questions presented in both English and Chinese, and they were allowed to answer in either English or Chinese for the free-response questions. At the same time, about one-third of the EMI students in each class were given a test paper written in English only. The two versions of the science achievement test were distributed randomly in the class during the data collection process. The use of two sets of test papers for the EMI students is to explore the effects of language of the test papers on the performance of the EMI students.

Some may argue for the use of a Chinese test paper instead of a bilingual paper for the EMI students to eliminate the confounding effect of language of the test paper on science achievement, so that the achievement of the EMI and CMI students can be compared on equal basis in terms of language of the test paper. This idea had been considered and tested at the beginning of the study, but it was found that many EMI students had greater difficulties in understanding the questions written in Chinese than in English. They had learned science content, together with its distinct terminology, complex discourse and grammatical structures, in English, and were alienated to similar content written in Chinese. Thus science questions written in English would make better sense to these students than those written in Chinese, and they would prefer English questions rather than Chinese questions. However, it was felt that bilingual questions would be helpful as the EMI students could refer to the Chinese version when they encountered difficult English expressions.

The questions in the science tests were set by experienced science teachers and moderated by two science educators of tertiary institutes for clarity of meaning and presentation. Each achievement test was piloted on a small sample of students in the schools taught by the setters. The questions of the achievement tests show a satisfactory reliability with a Cronbach value of 0.63 to 0.68.

The performance of the students on the science achievement tests is analysed by the following statistical methods:

(a) Multiple comparisons of mean scores on science achievement

An analysis of variance (ANOVA) test is conducted to assess whether the mean scores on the Science Achievement Test are significantly different among the four school strata (i.e. EMI, CHIG, CMID and CLOW). If the overall ANOVA is significant, multiple comparisons of the means are conducted to compare the means between pairs of group means. This statistical analysis provides some preliminary information on whether the initial ability difference among the four school strata is maintained after implementation of the new language policy in 1998, especially between the EMI and CHIG schools.

(b) Multi-level analysis of factors affecting students' science achievement

In order to make a more quantitative comparison of the effects of the medium of instruction on science achievement among the four school strata, a statistical technique called multi-level analysis (Bryk and Raudenbush, 1992; Goldstein, 1987) is used to control and identify the effects of students' prior characteristics that may have significant effects on students' performance. These student features include pre-entry ability, gender and socio-economic status. In this way, the science achievement of different school strata can be measured on the basis of a common index. The analysis involves two levels of variables, one at the individual student level and the other at the school level. More specifically, the statistical programme Hierarchical Linear and Nonlinear Modeling (HLM5) (Raudenbush *et al.*, 2000) is used here. By examining the effects of different variables on the science achievement scores, a baseline model is constructed for comparison among the sampled schools. From the baseline model, the value-added components on science achievement for the different school strata can be worked out. Computing the value-addedness of the schools makes it possible to compare the degree of improvement of students' science achievement in schools adopting either Chinese or English as MOI.

(c) Comparison of mean scores of individual items between EMI and CHIG schools

In order to understand how science learning is affected by using a second language as the instruction medium, the mean scores of individual items of the Science Achievement Test of the EMI students are compared with that of the CHIG students. By identifying whether the performance of the EMI students on individual items is higher or lower than, or the same as that of the CHIG students, some of the problems experienced by the EMI students in learning science through a second language may be revealed. Analysis of the written responses of the EMI and CMI students to the free-response questions may also contribute to understanding of these problems.

3. Students' self-concept in science

In view of the close relationship between academic achievement and academic self-concept (Chapter 2, p.59-61), this study also explores the effects of MOI on the development of self-concepts in science by comparing the responses of the EMI and CMI students to a questionnaire. The S2 Science Achievement Test for the 99-Cohort is preceded by a questionnaire of 16 items which assess students' academic self-concepts and their perception of classroom climate of science lessons (Appendix 4). The students are instructed to spend about 5 minutes to complete this part and the remaining time, about 30 minutes, on the Science Achievement Test. As described on p.78, Items 1-7 measure students' self-concept in science, while items 8-16 assess the classroom climate of science lessons. Ratings on science self-concept (Items 1-7) are made on a 4-point response scale, with 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree, but item 5 is coded in the reverse order. The seven items on science self-concept are adapted from the Self-description Questionnaire (SDQ) instrument designed and validated by Marsh and his collaborators (Marsh, 1990b; Marsh and O'Neill, 1984).

Self-concepts in Chinese, English and Mathematics of the same student cohort are similarly assessed using an instrument containing seven items that are strictly parallel with the science self-concept scale, i.e. the wording of the items is the same except for the names of the subject such as *Chinese*, *English* and *Mathematics*. With these instruments, it is possible to compare the academic self-concepts of students in different MOI streams and different ability strata within the CMI schools. The results also allow a comparison of the development of students' self-concepts in different academic subjects, especially between science and other subjects.

4. Instructional activities in science lessons

(a) Students' perceptions of classroom climate

In the questionnaire preceding the S2 Science Achievement Test, Items 8-16 measure students' perception of classroom climate in science lessons. These items are descriptions of common activities occurring in science lessons of secondary schools in Hong Kong. Students are asked to respond to these items on a 4-point scale, with 1 = never happen, 2 = rarely happen, 3 = sometimes happen, and 4 = always happen. Using this inventory, it is possible to compare the modes of instructional activities in science lessons, as perceived by the students, between different MOI streams and among different ability strata of the CMI schools.

Table 2 *Factor analysis of 99-Cohort students' perception of mode of instructional activities in science lessons*

(a) Factor loading

Structure Matrix		
	Factors	
	1	2
1. Exposition activities		
8 Students listen to teachers' explanation of subject content.	.676	.103
9 Teachers ask students questions related to the subject.	.642	.309
13 Students watch teachers' demonstration in the experiment laboratory.	.637	.080
12 Teachers manage classroom order.	.629	.079
14 Students follow the instruction of manual to conduct experiments.	.602	.045
16 Teachers check the answers on the work sheets with us.	.598	.056
10 Students ask teachers questions related to the subject.	.517	.516
2. Student-centred activities		
15 Students design the procedures of experiment themselves.	-.131	.769
11 Students conduct group discussion.	.302	.677

N = 17039 Total Variance Explained = 45.019%

(b) Component correlation matrix

Component Correlation Matrix			
	Component	1	2
1	Exposition activities	1.000	
2	Student-centred activities	0.173	1.000

Exploratory factor analysis is carried out on the students' responses for Items 8-16, using SPSS programme. The results of this analysis (Table 2a) produce two distinct factors. The first factor is concerned with exposition activities that occur between teachers and students in the classroom and the laboratory, while the second factor is concerned with the occurrence of student-centred activities. The correlation coefficients among the factors are relatively small and is statistically insignificant (Table 2b). They suggest that there are two distinct types of instructional activities taken place in science lessons: exposition activities and student-centred activities.

(b) Classroom observation

In this part of the study, ten S2/S3 science lessons were randomly selected for classroom observations, five from EMI schools and five from CMI schools (Table 3), after obtaining consent from the principals of the schools and the teachers concerned.

Table 3 *The nature and features of the ten science lessons observed*

Lesson	**School**	**Stratum**	**Grade**	**Topic of lesson**	**Activities**
E-1	CLS	EMI	S3	Energy requirement	Lecture on balanced diet and factors affecting energy requirement
E-2	TH		S2	Neutralisation	Lecture on acids and alkalis and instruction on neutralization practical + group experiment + checking answers with class
E-3	LTP		S2	Heat transfer	Lecture on ways of heat transfer: conduction, convection and radiation
E-4	LTP		S3	Electrolysis	Instruction and demonstration on setting up experiment on electrolysis + practical + checking answers with class
E-5	LP		S3	Food tests	Instruction on food tests + group experiment + discussion of results with class
C-1	SY	CMID	S2	Acids and alkalis	Lecture on acids and alkalis with applications in everyday life + demonstration + discussion
C-2	YY	CMID	S2	pH indicators	Lecture on detergents as acids and alkalis, and pH indicators + group experiment on pH indicators
C-3	CA	CHIG	S3	Lens	Lecture on properties of convex lens + instruction on practical + group experiment on convex lens
C-4	TKP	CHIG	S2	Weight and mass	Lecture on gravity and distinction between weight and mass + students doing exercise on textbook
C-5	CSA	CHIG	S2	Focusing with the eye	Lecture on focusing of the eye and eye defects + demonstration using the eye model

The classroom observations were made in the second term of the 2000-01 school year between March and June 2001. Bearing in mind that teaching styles are strongly affected by the ability and discipline of the students, the low-ability CMI schools (i.e. CLOW stratum) are excluded from this exercise, as some their students show negative learning attitudes and behaviour which will confound the interpretation of the classroom observation data in relation to the effects of MOI on instructional activities. Subsequently, the five CMI classes were selected from the CHIG and CMID strata, so that a more valid comparison could be made about the teaching styles and instructional activities between the EMI and CMI schools. With the consent of the teachers, these lessons were also videotaped. All lessons observed were single-period, ranging from 35 to 40 minutes.

As described on p.79, an 18-item Science Lesson Evaluation Guide (Appendix 5) is used to evaluate the teaching style, questioning skills and communication skills of the science teachers. Each item is scored on a 5-point scale, ranging from 1 = rarely/weak to 5 = always/good. For example, for Item 1 ("*Pupils listen to teacher's explanation*"), a value of 3 indicates that for the particular lesson, pupils listen to the teacher's explanation for some of the time, while a value of 5 indicates that the class listens to the teacher's explanation for most time of the lesson. For Item 14 ("*Quality of explanation*"), a value of 1 is assigned to a lesson in which the teacher's explanation is poor and incomprehensible, while a value of 5 for a lesson in which the teacher's explanation is accurate and comprehensive.

Each lesson is assessed according to the Science Lesson Evaluation Guide by the author and another science educator who is also experienced in training science teachers. Assessment is made by viewing the videotaped lessons as well as direct observation in the classroom, which was mainly made by the author. The two scores on each item from the two assessors are matched, and discrepancies in scoring are settled through discussion and negotiation between the assessors.

STRENGTHS OF THE METHODOLOGY OF THE PRESENT STUDY

As the new language policy of the *Guidance* advocates a late immersion model for selected students with high academic and English proficiency, the findings of this study will contribute to understanding the problems of science learning for students learning through a second language which is quite different from the native language in linguistic structure. Compared with previous local studies on the effects of medium of instruction on science learning, the present study is more systematically and vigorously designed. The methodology used in this study has the following strengths:

(a) The study involves a longitudinal study of a large representative sample;

(b) The differences in prior achievement of individual students, in terms of the Academic Aptitude Index, and other student variables are controlled.

(c) The science achievement and self-concept of students are assessed by well validated instruments;

(d) The use of multilevel modeling technique allows a better differentiation of the effects due to individual students and schools than the multiple regression analyses used in some of the previous studies;

(e) Data on students' perception of classroom climate and direct classroom observation help to establish possible relationships between the effects of MOI on science achievement and the modes of instructional activities in science lessons.

(f) Since according to the new language policy, mixed code teaching is not allowed, the effects of the medium of instruction on student learning can potentially be identified more accurately;

(g) The new policy ensures that students receiving English-medium instruction have reached an adequate level of English proficiency. This allows a more valid evaluation of the effects of MOI on science learning for such students.

PRESENTATION AND DISCUSSION OF RESULTS

Data are collected at different stages of the study according to the research framework and methodology outlined in the previous sections. As the findings at one stage will inform the work at a later stage, there is a logical and chronological relationship between the various stages. In subsequent chapters, the results of different stages of the study are presented in an order that shows how they are related to each other and built on each other, so as to construct a coherent picture of the effects of MOI on science learning. The chapters that report on the results and findings of the present study are as follows:

Chapter 4: The effects of MOI on students' science achievement

Chapter 5: The effects of MOI on students' science self-concept

Chapter 6: The effects of MOI on instructional activities in science lessons

Chapter 7: Changes in the effects of MOI on students' science achievement over time

Chapter 8: Implications and recommendations

CHAPTER 4

THE EFFECTS OF MEDIUM OF INSTRUCTION ON STUDENTS' SCIENCE ACHIEVEMENT

INTRODUCTION

In this study, as pointed out in Chapter 3, the outcomes of science learning are conceptualised as consisting of academic achievement and self-concept, and the effects of MOI on science achievement are measured by students' performance on three science achievement tests. This chapter reports and analyses the performance of the 1999 student cohort on these tests. The students of this cohort entered S1 in September 1999. They attempted the science achievement tests near the end of each academic year from S1 to S3, i.e. in April to June of 2000, 2001 and 2002 respectively. These tests enable us to track the impact of MOI on students' science achievement for the first three years of secondary schooling. Data analysis of the performance on each science achievement test includes:

* Mean performance and multiple comparison of the performance of the four school strata (EMI, CHIG, CMID and CLOW) on the science achievement test
* Mean performance and multiple comparison of the performance of the EMI and CHIG strata on individual multiple-choice and free-response items

In this chapter, the performance of the 99-Cohort of students in S2 will be discussed in detail, whereas their performance in S1 and S3 will be treated more briefly for comparison purposes. These findings will lead us to arrive at some preliminary conclusions about the impact of MOI on the learning of science. To study the possible effects of the test language on the performance of the EMI students, two versions of science achievement test were used. Two-thirds of the EMI students worked on a bilingual paper while one-third of them worked on an English paper. The effects of this treatment will be dealt with on p.130. In the following sections that compare the performance of the EMI and CMI students on the achievement tests, the EMI students are considered as a whole group.

PERFORMANCE ON THE S2 SCIENCE ACHIEVEMENT TEST

The S2 Science Achievement Test consists of two parts (Appendix 2). Part A contains 26 multiple-choice questions, each with four options. This part assesses students' knowledge and understanding in subject matter covered in the S2 science curriculum recommended by the Education Department (CDC, 1986). Part B contains three free-response questions with a total of 9 marks. These questions assess students' communicative skills as well as their knowledge and understanding in science.

The questions in both parts were set by experienced science teachers and were moderated by two science educators of tertiary institutes for clarity of meaning and presentation. The questions show a satisfactory reliability with alpha value of 0.632.

1. Multiple comparison of the mean performance among the four school strata

The 99-Cohort attempted the S2 Science Achievement Test in April to June of 2001. If the students progress at a similar pace in science learning through S1 to S2, the science achievement scores of the students of the four school strata near the end of S2 should be correlated with their initial academic abilities as measured by their AAI scores, which are compared in Table 1 (Chapter 3, p.81). This means that the students of one stratum should perform better than those of the next lower stratum. This prediction can be tested by comparing the mean scores of the S2 Science Achievement Test of any two successive school strata.

Table 4 shows the mean scores of the four school strata on the S2 Science Achievement Test and the analysis of variance of the mean scores among the four strata. For the three CMI strata, the performance is closely related to the initial student abilities at S1 entry, as the mean score of each stratum is significantly higher than that of the next lower stratum, i.e. CHIG > CMID > CLOW. This result indicates that the AAI of individual students, a score based on students' academic performance in school-based examinations in the last two years of primary education moderated by a public aptitude test, is a reliable indicator of the academic potential of the students in secondary schools.

The EMI stratum, on the other hand, performed less satisfactorily than the CHIG stratum, and the difference between their mean scores is significant at the 0.001 level. This result indicates that the EMI students not only failed to maintain a higher achievement in science than the CHIG students after two years of secondary education, as would be expected on the basis as their higher prior ability, but showed a significantly lower performance in the Science Achievement Test. Since the EMI students were academically more able than the CHIG students initially, they must have been somehow disadvantaged in science learning after entering secondary schools. A possible factor is the medium of instruction for science lessons, which is a key difference between the classroom setting of the EMI and CHIG schools.

Table 4 *Mean scores of different school strata on the S2 Science Achievement Test and comparison of the means*

		EMI	CHIG	CMID	CLOW
N		4624	3630	4552	3969
Mean (%)		44.91	48.98	43.11	35.64
Std. Deviation		12.54	13.23	13.90	14.08
Difference of the means	EMI	-	-4.07*	1.80*	9.27*
	CHIG	-	-	5.87*	13.34*
	CMID	-	-	-	7.469*

* The difference of the means is significant at the 0.001 level.

To account for the poorer performance of the EMI students in the science test, it is reasonable to suggest that they are disadvantaged in science learning by receiving instruction in English, or that the CMI students are facilitated by using Chinese as the medium of instruction. During the primary years, the EMI students learned English as a separate subject and other subjects in Chinese. When they enter the secondary schools, their proficiency in English is far below that in Chinese (Johnson and Cheung, 1992; Johnson and Lee, 1987). By following a total English immersion programme for all content subjects, including science, immediately in S1 with little provision for bridging the gap between the high language demand for science learning and the relatively low English proficiency of the students, the EMI students should find it extremely difficult to master the special terminology of science and to understand the abstract concepts and relationships in science. The validity of this interpretation for the differential performance of the EMI and CMI students can be tested by item analysis of the Science Achievement Test (in the next section of this Chapter) and examination of the instructional activities taking place in science lessons (Chapter 6). Nevertheless, the present observation that the CHIG students show higher science achievement than the EMI students challenges the basic assumption made in the new language policy that the EMI students, who are selected into the English-medium secondary schools because of their higher academic abilities, should be capable of learning science effectively in English.

2. Multi-level analysis of factors affecting science achievement

(a) Effects of AAI on science achievement

The first set of hierarchical linear models constructed is a two-level hierarchical model for students nested within schools. It is designed to examine the effects of prior ability on science achievement, and does not include any explanatory variables such as gender or socio-economic status of the students. The independent variables are individual students' AAI and schools' mean AAI, and the dependent variable is the achievement scores in the Science Achievement Test. This base-line model shows the degree of segregation, or segregation index, in students' initial academic ability among the sampled schools (Table 5). According to Willms and Raudenbush (1989), segregation index is the percentage of total variance in a variable that lies between schools, i.e. the ratio of between-school sum of squares to the total sum of squares.

Table 5 *Partition of variance in the S2 science achievement scores*

	AAI (99)	S2 Science Scores
Student-level variance	0.439	0.767
School-level variance	0.922	0.237
% of within-school (student-level) variance	32.26%	76.39%
% of between-school (school-level) variance	67.74%	23.61%

The total variance σ_T^2 of the test scores is made up of two components, the student-level variance σ_P^2 and the school-level variance σ_S^2., i.e. $\sigma_T^2 = \sigma_P^2 + \sigma_S^2$. The segregation index of AAI shows that Hong Kong students are highly segregated in academic ability when they enter secondary schools. The high percentage of between-school variance (67.74%) indicates that two-third of the total variance of AAI is among schools, and only one-third of the total variance (32.26%) is among students within schools. This means that students within each school are relatively homogeneous in terms of academic ability, while the schools show wide variation in the academic ability of their S1 intake.

For the science scores of the present student cohort, the segregation index is 23.61% (Table 5), which is much smaller than the segregation index for AAI. This indicates that the initial wide gap in students' academic ability among the sampled schools have been narrowed down over time with reference to science achievement. A possible explanation of this finding is that the EMI students, though with a higher prior ability, are disadvantaged in science learning by adopting a second language as the medium of instruction. The CMI students, on the other hand, can learn science more effectively in their mother tongue. Thus the gap in academic ability, in terms of science achievement, between the EMI and CMI schools has become narrower after two years of secondary schooling. This interpretation is consistent with the finding that the performance of the EMI students on the S2 Science Achievement Test is lower than that of the CHIG students (Table 4, p.96). This idea can also be tested by item analysis of the performance of the EMI and CMI students on the science achievement test.

Apart from the baseline model, it is also meaningful to examine the student-background and contextual effects of AAI on science achievement. In the present study, these refer to the effects of individual students' AAI and the school mean AAI respectively. The results of the multi-level analysis are summarized in Table 6.

Table 6 *Effects of prior ability on the S2 science achievement scores*

	Null Model			**Model 1**		
Fixed effects	Estimate		Standard error	Estimate		Standard error
Pupil level (L1)						
Intercept	0.458		0.049	0.535*		0.033
AAI				0.561*		0.019
School level (L2)						
AAI effects on mean scores				- 0.175*		0.038
Random effects	Estimate	df	Chi-square	Estimate	df	Chi-square
L1 variance (σ^2)	0.767			0.707		
% of L1 σ^2 explained				7.86%		
L2 variance (σ^2)	0.237	99	4799.888	0.104	98	1201.385
% of L2 σ^2 explained				56.28		

* Significant at the 0.05 level

The results in Table 6 show that the effects of individual AAI and school mean AAI are statistically significant. The individual AAI has a positive effect on science achievement. As the AAI of individual students increases by one unit of a standard deviation, the science achievement score will increase by 0.561 of a standard deviation unit.

However, the contextual effect of AAI on science achievement is rather different. The coefficient (−0.175) for the effect of the school mean AAI on science achievement is statistically significant but negative in value. The negative value indicates that the school mean AAI has a negative effect on the intercept, implying that a higher school mean AAI is associated with a lower science achievement score. This apparently irrational relationship is a likely consequence of the effects of different media of instruction adopted by the sampled schools. While the EMI schools in general have a higher mean AAI than the CMI schools, their students are found to perform less satisfactorily on the achievement test, probably because they are disadvantaged in science learning by receiving instruction in English. This interpretation is consistent with the previous observation that the science achievement of the student cohort has a much lower segregation index than that of AAI.

(b) Effects of sampling strata on science achievement

In order to differentiate the school contextual effects on science achievement, we can replace the school mean AAI with three dummy variables. The dummy variables are the CHIG, CMID and CLOW strata, using the EMI stratum as the reference point. When these dummy variables are injected into the baseline model to replace the school contextual measure, i.e. school mean AAI, a new set of hierarchical linear model is constructed. This model will enable us to compare the EMI students with the students of the three CMI school strata with respect to their performance on the science achievement test, and compute the magnitude of the effects of the medium of instruction on science learning. The equations for this multi-level regression model are as follows:

Level 1 model: $Y = \beta_0 + \beta_1(ZAAI) + \beta_2(ZSES) + \beta_3(Female) + r$

Level 2 model: $\beta_0 = \gamma_{00} + \gamma_{01}(ZAAI) + \gamma_{02}(ZSES) + \gamma_{03}(CHIG) + \gamma_{04}(CMID) + \gamma_{05}(CLOW) + \mu_0$

The effects of the sampling strata on science achievement as identified by this hierarchical linear model are summarised in Table 7. At the student level, student AAI has a positive effect on science achievement, whereas being a female has a small negative effect on science achievement. However, the socio-economic status of the students' family does not have any statistically significant effect on science achievement.

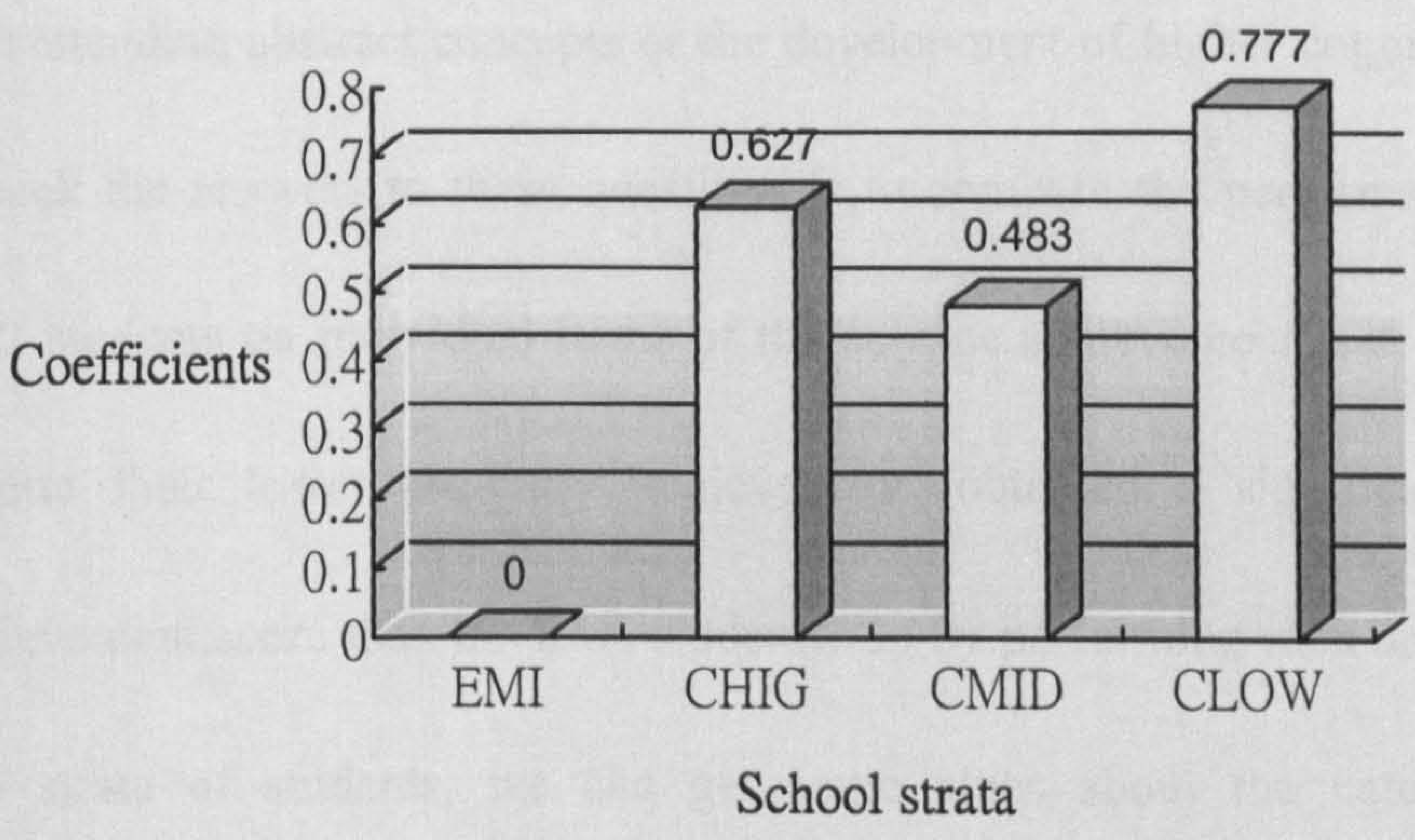
The coefficients of the three CMI school strata on science achievement, with reference to the EMI stratum, are all statistically significant and positive in value. The data indicate that the three CMI strata substantially outperformed the EMI stratum in the science achievement test, after controlling student and school mean AAI and SES. More specifically, the CHIG, CMID and CLOW students outperformed the EMI students by 0.627, 0.483 and 0.777 of a standard deviation in science achievement respectively, after controlling student and school mean AAI and socio-economic status (Figure 2).

Table 7 *Effects of sampling strata on the S2 Science Achievement Scores*

	Null Model			Model 2		
Fixed effects	Estimate		Standard error	Estimate		Standard error
Pupil level (L1)						
Intercept	−0.064		0.048	−0.483*		0.113
AAI				0.384*		0.017
Female				−0.080*		0.016
SES				0.003		0.007
School level (L2)						
AAI effects on mean scores				0.196		0.106
SES effects on mean scores				0.047		0.074
CHIG effects on mean scores				0.627*		0.088
CMID effects on mean scores				0.483*		0.141
CLOW effects on mean scores				0.777*		0.235
Random effects	Estimate	df	Chi-square	Estimate	df	Chi-square
L1 variance (σ^2)	0.675			0.638		
% of L1 σ^2 explained				5.45%		
L2 variance (σ^2)	0.214*	94	5269.437	0.080*	69	382.665
% of L2 σ^2 explained				62.69		

* Significant at the 0.05 level

Figure 2 *Coefficients of the different school strata on science achievement, with that of the EMI stratum set at 0*



This finding once again suggests that using English as a medium of instruction has a negative effect on science learning. Although the EMI students have a higher prior academic ability than the CMI students, their relatively low science achievement suggests that their proficiency in English is not high enough to enable them to learn science effectively. The subject content of science involves a lot of abstract concepts and complex relationships, the accurate use of scientific terminology and the application of scientific knowledge and skills to solve problems. All these demand a high level of language proficiency (Gonzalez, 1998; Rollnick, 2000). Thus the CMI students, who can communicate effectively in their mother tongue, will have a linguistic advantage over the EMI students in the learning of science.

3. Item analysis of the multiple-choice and free-response questions

How can we account for the unsatisfactory performance of the EMI students in comparison with the CMI students? In what aspects are the EMI students particularly constrained in science learning? Is it related to the mastery of scientific terminology, the understanding abstract concepts or the development of higher cognitive skills? One way to seek the answers to these questions is to compare the performance of the EMI and CMI students on individual items of the science achievement test. The CHIG students, despite their lower pre-entry achievement, obtained a significantly higher science achievement score than the EMI students. So by performing item analysis between these two strata of students, we can get some clues about the nature of the problems experienced by the EMI students when they learn science through a second language instead of in their mother tongue.

Of the total 26 multiple-choice questions in the S2 Science Achievement Test, three items have been deleted from the process of statistical analysis because they show very low or even negative discrimination index, i.e. below 0.2. These are Items 11, 19 and 26. For Item 11, only a very small percentage of students of all strata (ranging from 4.2 to 8.2%) could answer correctly that the semicircular canals of the ear are concerned with detecting body movement, whereas a large number of the students erroneously considered that the function of the semicircular canals is to conduct sound vibrations to the cochlea (40.7%), to detect sound vibrations (21.1%), or to control body balance (32.5%). A possible reason for this pattern of response is that the functions of different parts of the mammalian ear is only treated briefly in the S2 science curriculum, with a focus on the hearing function only. Thus many students may not know the function of the semicircular canals, and for those who possess superficial understanding of the topic, it is difficult for them to distinguish the subtle difference in meaning between the detection and control of body balance. The same reason may also be used to account for the low discrimination and low success rate of Item 19, which assesses the effects of connecting lamps in parallel or in series in an electric circuit. Item 26 is concerned with identifying the forces acting on a golf ball moving in air. This is a very demanding question that assesses in-depth understanding of the concept of force. The poor and indiscriminative performance on this item suggests that most S2 students, irrespective of the medium of instruction used, fail to develop a conceptual understanding of the nature of force despite that this topic is covered in the S2 science curriculum.

(a) Multiple-choice items in which the EMI students out-performed the CHIG students

Out of the remaining 23 multiple-choice questions in the S2 Science Achievement Test, the EMI stratum performed better than the CHIG stratum in 5 items only (i.e. Items 1, 7, 8, 21 and 22), at a level of significance of $p<0.05$ (Table 8).

Table 8 *Performance on multiple-choice items of the S2 Science Achievement Test in which the EMI students out-performed the CHIG students*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
1	EMI	.310	.463	-0.033	0.005
	CHIG	.277	.448		
7	EMI	.600	.490	-0.039	0.003
	CHIG	.561	.496		
8	EMI	.397	.489	-0.030	0.031
	CHIG	.368	.482		
21	EMI	.517	.500	-0.030	0.036
	CHIG	.486	.500		
22	EMI	.783	.412	-0.072	0.001
	CHIG	.711	.453		

Most of these items require direct recall or simple application of science concepts. For example, Item 1 asks for the most abundant gas in the exhaled air; Item 7 requires the identification of substances that turn blue litmus paper red; Item 8 is concerned with a deficiency symptom of vitamin A. The EMI students also out-performed the CHIG students in questions that assess simple chemistry concepts, e.g. the reaction between water and metals (Item 21), and the test for hydrogen gas (Item 22).

(b) Multiple-choice items in which the EMI and CHIG students showed similar performance

For most of the multiple-choice items, the performance of the CHIG students is as good as or better than that of the EMI students. There are 9 items for which the mean score of the CHIG stratum is comparable to that of the EMI stratum (Table 9).

Table 9 *Performance on multiple-choice items of the S2 Science Achievement Test in which the EMI and CHIG students showed comparable performance*

Item	Stratum	Mean	Standard deviation	Difference of the means
2	EMI	.268	.443	-0.018
	CHIG	.286	.452	
5	EMI	.459	.498	-0.072
	CHIG	.531	.499	
6	EMI	.300	.458	-0.038
	CHIG	.338	1.383	
13	EMI	.319	.466	-0.008
	CHIG	.312	.463	
15	EMI	.515	500	-0.010
	CHIG	.505	.500	
16	EMI	.653	.476	-0.023
	CHIG	.629	.483	
17	EMI	.377	.485	-0.008
	CHIG	.368	.482	
23	EMI	.273	.446	-0.024
	CHIG	.297	.457	
24	EMI	.638	.480	-0.027
	CHIG	.665	.472	

Some of these items are concerned with knowledge of experimental set-ups or the application of science concepts to explain everyday experiences, such as to state the importance of using a water bath for heating alcohol (Item 2), to account for the changes observed in a respirometer (Item 13), to identify the conditions for producing an alkaline solution (Item 23), and to explain why microscopic algae are abundant at the water surface (Item 24). Some items require the students to apply science concepts to predict experimental results, such as identifying the paper card that will burn quickest under sunlight focused with a lens (Item 5), comparing the resistance of wires of different length and diameter (Item 15), predicting the brightness of different light bulbs connected in series (Item 16), and estimating the effect of short circuiting on the brightness of light bulbs (Item 17).

(c) Multiple-choice items in which the CHIG students out-performed the EMI students

Table 10 *Performance on multiple-choice items of the S2 Science Achievement Test in which the CHIG students out-performed the EMI students*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
3	EMI	.604	.489	-0.056	0.001
	CHIG	.660	.474		
4	EMI	.513	500	-0.277	0.001
	CHIG	.790	.407		
9	EMI	.380	.485	-0.037	0.003
	CHIG	.417	.493		
10	EMI	.358	.479	-0.084	0.001
	CHIG	.442	.497		
12	EMI	.651	.477	-0.076	0.001
	CHIG	.727	.446		
14	EMI	.298	.458	-0.028	0.038
	CHIG	.326	.469		
18	EMI	.770	.421	-0.049	0.001
	CHIG	.819	.385		
20	EMI	.842	.364	-0.035	0.001
	CHIG	.877	.329		
25	EMI	.722	.448	-0.043	0.001
	CHIG	.765	.424		

For the remaining nine multiple-choice items, the CHIG students performed better than the EMI students and the difference of means is significant at the 0.05 level (Table 10). Some of these items are concerned with experimental designs. For example, Item 3 requires the students to identify the aim of an investigation on photosynthesis by comparing two experimental set-ups; Item 4 assesses understanding of the concept of destarching a plant before the experiment; Item 14 asks the students to suggest how to obtain the results from a respirometer more rapidly.

For Item 3, students are expected to possess the knowledge that sodium hydroxide removes carbon dioxide from the jar, and they have to compare the two set-ups to find out the effect of carbon dioxide on photosynthesis (option D). A much greater number of the EMI students than the CHIG students erroneously thought that the experiment is designed to test whether water is necessary for photosynthesis (option B). This indicates that these students had not mastered the concept of control in designing experiments, so they failed to appreciate the role of the sodium hydroxide solution in removing carbon dioxide from the control set-up. Although destarching a plant is a prerequisite condition for experiments on photosynthesis, the poor performance of the EMI students on Item 4 in comparison with the CHIG students indicates that the EMI students did not understand this idea and many of them erroneously thought that keeping the plants in the dark before the experiment is to allow time for the plants to absorb water (option B) instead of to ensure that the leaves contain no starch at the beginning of the experiment (option D).

Some items are concerned with the application of science concepts in realistic or unfamiliar situations, i.e. Items 9, 20 and 25. These questions assess the ability to integrate and apply concepts rather than memory work. For example, Item 9 involves the identification of the ray diagram that indicates a short-sighted condition. In order to answer this question correctly (choosing option A), students need to determine the nature of light rays from a distant object, and to identify the location of the image formed inside the eyeball. A significant proportion of the EMI students chose options C (32%) and D (22%), indicating that many of them could not distinguish between the effects of short-sight and long-sight.

Item 20 asks the students to explain why a lighted candle goes out when covered by a jar. While most students could point out correctly that it is due to a lack of oxygen (option C), a much greater proportion of the EMI students than the CHIG students erroneously thought that the accumulation of carbon dioxide inside the jar turns out the flame (option B). This is an informal preconception commonly shown by children before they receive science instruction on burning (Driver, 1993). The result suggests that it may be easier for children to replace their informal preconceptions with proper science concepts if they learn science in their native language instead of in a second language.

Item 25 assesses understanding of the cause of global warming, a complex phenomenon that involves the integration of a number of concepts such as photosynthesis and greenhouse gases. A much greater proportion of the EMI students than the CHIG students mixed up global warming with the depletion of the ozone layer (option D). This misunderstanding is widespread among children, and it persists even after formal instruction (Anderson and Wallin, 2000; Potts *et al.*, 1996). The confusion probably arises from the fact that the two phenomena share some common features, such as both are of global dimension and involve CFCs, which damage the ozone layer and also act as greenhouse gases (Stanisstreet and Boyes, 1996). The present result provides further support to the above assertion that children can dispel their informal preconceptions more readily if they receive instruction in their native language than in a second language. This is particularly true for alternative conceptions that are very resistant to change.

The EMI students performed less satisfactorily than the CHIG students in some multiple-choice items that appear to be quite straight forward and of low cognitive demand (i.e. Items 10, 12 and 18). Closer examination of these questions reveals that they assess students' understanding of the precise meaning of certain concept terms in science. For example, when answering Item 10, which is about the functions of the ear bones, the students had to distinguish between the meanings of "to magnify vibrations", "to transmit vibrations" and "to equalize the pressure on both sides of the tympanum". As illustrated by this question, the terminology and language of science is quite different from everyday language, and this difference makes science difficult to understand even for native speakers (Garraway, 1994). This problem would be even greater for non-native speakers as they are given the double task of learning the language of science through the medium of a foreign language that they are less proficient with.

The EMI students experienced a similar problem for Item 12. They had to understand the scientific meaning of '*force*', and associate it with the concepts of '*gravity*', '*friction*', '*weight*' and '*mass*'. All these terms denote some abstract scientific concepts, which demand higher cognitive skills for understanding. It is also quite easy for children to confound the everyday meaning of '*force*' with its specific scientific meaning, particularly when teaching is conducted through a second language. Furthermore, the abstract nature and the subtle differences between the meanings of some of these concepts are difficult even for adolescent students. The same reason can also account for the poorer performance of the EMI students comparing with the CHIG students on Item 18, which assesses understanding of science terminology concerned with heat transfer, such as "radiation", "conduction" and "convection".

(d) Performance on the free-response items

The free-response items require students to apply their scientific concepts and organize their reasoning to explain various physical phenomena. Such questions make a high demand on concept understanding, high-level thinking and communication skills. The CHIG students performed better than the EMI students in all the three items and the differences in mean scores are significant at the 0.001 level (Table 11). This implies that the CHIG students had a better grasp of the concepts involved and they demonstrated a higher ability to integrate and articulate their scientific knowledge. This is reflected from a comparison of the answers given by the two strata of students.

Item 27 asks students to explain why plants usually grow better in soils that contain dead bodies of plants and animals. When answering this question, many CHIG students mentioned the presence of dead organic matter and the decomposition process, whereas only a small number of EMI students could bring out these points. For Item 28, which asks students to explain why a stone would drop more slowly on the Moon than on the Earth, more CHIG students than EMI students were able to compare the size or mass of the Earth and the Moon, and relate this to the effects of different gravity on the stone. For Item 29, which is concerned with the rate of melting of an ice block in a room, more CHIG students predicted correctly that the ice block covered with a blanket will melt more slowly and explained their answers in terms of the heat-insulating property of the blanket.

Table 11 *Performance of the EMI and CHIG students on the free-response items of the S2 Science Achievement Test*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
27	EMI	.649	.596	-0.561	0.001
	CHIG	1.211	.605		
28	EMI	1.064	.719	-0.193	0.001
	CHIG	1.257	.766		
29	EMI	.918	.871	-0.186	0.001
	CHIG	1.105	.941		
Total score	EMI	2.632	1.442	-0.941	0.001
	CHIG	3.573	1.551		

When answering the free-response questions, the students had to organize their thoughts and present them in a logical and concise way. The EMI students apparently had greater difficulty in doing this than the CHIG students, as most of the written answers of the EMI students are made up of sentences with ambiguous meaning or disconnected ideas. Furthermore, not many of the EMI students were capable of using appropriate concept terms for their explanation, such as minerals, humus, decomposition, gravity and mass, heat insulation and heat gain. This shows that the EMI students had greater difficulty in mastering and using the terminology and language of science to verbalise their ideas than their CMI peers.

PERFORMANCE ON THE S1 SCIENCE ACHIEVEMENT TEST

1. Multiple comparison of the mean performance among the four school strata

The 99-Cohort attempted the S1 Science Achievement Test (Appendix 1) in April to June of 2000. Part A of the test contains 22 multiple-choice questions and Part B contains three free-response questions. The questions yield a satisfactory reliability with alpha value of 0.681. Table 12 shows the mean scores of the four school strata in this test and the analysis of variance of the mean scores among different school strata.

Table 12 *Mean scores of different school strata on the S1 Science Achievement Test and comparison of the means*

		EMI	CHIG	CMID	CLOW
N		4093	3491	4725	3805
Mean		47.72	50.43	43.19	34.11
Std. Deviation		13.53	12.88	13.34	13.69
Difference of the means	EMI	-	-2.72*	4.53*	13.61*
	CHIG	-	-	7.25*	16.32*
	CMID	-	-	-	9.08*

* The difference of the means is significant at the 0.001 level.

The analysis indicates that among the CMI schools, the science achievements of the students of the three strata (i.e. CHIG, CMID and CLOW) near the end of S1 were closely related to their prior academic abilities as based on AAI scores, with the mean test scores decreasing in the order of CHIG, CMID and CLOW. The EMI schools, however, were found to perform less satisfactorily than the CHIG schools, despite the higher prior achievement of their S1 student intake.

This pattern of response is similar to that observed in the performance on the S2 Science Achievement Test. The EMI students not only failed to maintain a higher achievement in science as predicted by their higher prior achievement, but performed less satisfactorily than the CHIG students. The difference between their mean scores is significant at the 0.001 level. To explore the causes of the lower achievement of the EMI students, item analysis is performed on the multiple-choice and free-response questions using multiple comparisons of the performance of different student strata.

2. Item analysis of the multiple-choice and free-response questions

Of the total 22 multiple-choice questions in the S1 Science Achievement Test, Item 12 has been deleted from the process of statistical analysis because it shows a low discrimination index of 0.058. Item 12 assesses understanding of burning as a chemical reaction between the atoms of a candle and the air. This appears to be a simple chemistry concept, but surprisingly only a very low percentage of students (15.9%) got it right. Most students erroneously thought that the atoms changed into heat and light during burning. It is interesting to note that among the CMI schools, the percentage of students holding this misconception is highest in the CHIG stratum (73.7%), and it drops with decrease in academic ability (67.7% in CMID and 60.0% in CLOW). In the EMI stratum, 65.7% of the students hold this alternative idea, and this may help to explain why the EMI stratum performed slightly better than the CHIG stratum in this item. The fact that a greater percentage of the more able students (i.e. EMI and CHIG students) were trapped by this distracter suggests that explaining burning in terms of reactions of atoms may be too abstract for junior science students, who tend to form a hybrid model for burning with a mixture of informal preconceptions and school science concepts.

(a) Multiple-choice items in which the EMI students out-performed the CHIG students

To account for the unsatisfactory performance of the EMI students in comparison with the CHIG students, item analysis is carried out for the two school strata. Out of the 21 multiple-choice questions in the S1 Science Achievement Test that show satisfactory discrimination, the EMI stratum performs better than the CHIG stratum in two items only (i.e. items 6 and 9), at a level of significance of $p<0.001$ (Table 13).

Table 13 *Performance on multiple-choice items of the S1 Science Achievement Test in which the EMI students out-performed the CHIG students*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
6	EMI	.738	.440	.086	0.001
	CHIG	.651	.477		
9	EMI	.418	.493	.059	0.001
	CHIG	.360	.480		

These items require direct recall or simple application of science concepts. Item 6 is concerned with a concrete concept about the shape of liquid in a container; Item 9 is a recall-type question asking for the types of compounds formed in chemical reactions.

(b) Multiple-choice items in which the EMI and CHIG students showed similar performance

Table 14 *Performance on multiple-choice items of the S1 Science Achievement Test in which the EMI and CHIG students showed comparable performance*

Item	Stratum	Mean	Standard deviation	Difference of the means
1	EMI	.854	.353	0.008
	CHIG	.846	.361	
5	EMI	.501	.500	-0.022
	CHIG	.523	.500	
8	EMI	.705	.456	-0.006
	CHIG	.711	.453	
11	EMI	.606	.489	-0.009
	CHIG	.615	.487	
15	EMI	.240	.427	-0.001
	CHIG	.241	.428	
17	EMI	.664	.473	0.010
	CHIG	.653	.476	
18	EMI	.695	.460	0.019
	CHIG	.676	.468	
19	EMI	.822	.383	0.015
	CHIG	.807	.395	
20	EMI	.436	.496	-0.003
	CHIG	.439	.496	
21	EMI	.347	.476	0.020
	CHIG	.327	.469	
22	EMI	.909	.287	-0.015
	CHIG	.925	.263	

For most of the multiple-choice items, the CHIG students performed as well as or better than the EMI students. Of the 21 multiple-choice questions, the mean scores of the

CHIG stratum on 11 items are comparable to those of the EMI stratum, i.e. there is no significant difference between the means of the EMI and CHIG strata in each of these items (Table 14).

Some of these items involve the application of science concepts to explain everyday experiences, such as to explain the disappearance of water and petroleum in terms of evaporation (Item 1), to account for the loss in mass of a salt solution (Item 15), to apply the particle theory of matter to explain expansion (Item 17), to explain the rolling of a ball in terms of different forms of energy (Item 18), and to explain the inflation of a heated balloon using the kinetic theory (Item 20). Some items assess the understanding of chemistry concepts, such as identifying the nature of the product of a chemical reaction between iron and sulphur (Item 5) and a calculation based on the concept of solubility (Item 8).

From the above analysis, the EMI students seemed to be constrained in using abstract scientific constructs or models, such as the particle model of matter, kinetic theory and the atomic nature of matter.

(c) Multiple-choice items in which the CHIG students out-performed the EMI students

For the remaining 8 multiple-choice items, the CHIG students performed better than the EMI students at a level of significance of $p<0.001$ (Table 15). Some items are concerned with the application of science concepts in realistic or unfamiliar situations, i.e. Items 4, 7 and 13. These questions assess the understanding of and the ability to integrate various concepts rather than memory work. For example, Item 4 is concerned with the application of the knowledge of expansion to loosen a metal lid on a jar. Item 7 asks for the quickest way to dissolve sugar in water. Item 13 assesses understanding of the chemistry of burning, demanding an explanation for the blackening of the bottom of a dish after heating with a luminous flame.

Table 15 *Multiple-choice items of the S1 Science Achievement Test in which the CHIG students out-performed the EMI students*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
2	EMI	.675	.468	-0.082	0.001
	CHIG	.757	.429		
3	EMI	.645	.478	-0.053	0.001
	CHIG	.698	.459		
4	EMI	.779	.415	-0.049	0.001
	CHIG	.828	.377		
7	EMI	.815	.388	-0.097	0.001
	CHIG	.912	.282		
10	EMI	.431	.495	-0.055	0.001
	CHIG	.486	.500		
13	EMI	.499	.500	-0.079	0.001
	CHIG	.577	.494		
14	EMI	.659	.474	-0.048	0.001
	CHIG	.707	.455		
16	EMI	.150	.357	-0.046	0.001
	CHIG	.195	.396		

Certain items assess understanding of the distinction between physical and chemical changes. Item 2 is a problem on the use of filter paper in separating substances in a solution or a mixture. Item 3 requires the students to identify whether certain everyday life phenomena involve chemical changes, such as the melting of wax on heating, the rusting of copper in air and the boiling of alcohol. These two items are based on simple and familiar contexts, and more than half of the students in both strata (i.e. EMI and CHIG) answered them correctly. However, a greater proportion of EMI students, despite their initial higher academic ability, showed a poor understanding of the principle of filtration, and suggested to use this method to separate substances in solutions and a mixture of solid particles. The EMI students also had greater problems with the concept of chemical reactions, as a greater percentage of them thought that melting of wax and boiling of alcohol are chemical changes.

A few items are concerned with the application of the particle model to explain various properties of matter, such as the formation of crystal from a saturated solution (Item 10), and the greater compressibility of gases than liquids (Item 14). Comparing with the CHIG students, more EMI students erroneously thought that the shape of the crystals formed from a saturated solution is not dependent on the substance dissolved, and that larger crystals will be formed if the solution cools down more quickly. More EMI students than CHIG students failed to relate the higher compressibility of gases than liquids to the greater distance between the gas particles.

Item 16 appears to be a low-level question that involves the identification of plants that produce flowers. However, only about 17% of the students considered correctly that grass produces flowers. Most students failed in this item because, based on their own experience, grass does not appear to produce any flowers. This misconception is probably related to the fact that grass produces many small and inconspicuous flowers adapted for wind-pollination. This erroneous view is held by many science students even when they reach S5 (equivalent to grade 11) as well as some science teachers (Mak *et al.*, 1999). Many students, particularly the EMI students, thought that the fern or moss produces flowers. 'Fern' and 'moss' are terms of plant groups that are novel to S1 students, irrespective of their medium of instruction. The particularly high percentage of EMI students opting for these two choices suggests that students learning science in a second language may experience greater difficulty in mastering new and unfamiliar terminology.

(d) Performance on the free-response items

The free-response items require the students to apply their scientific concepts to explain various physical phenomena. The overall performance of the CHIG students in this part is significantly better than that of the EMI students (Table 16), implying that the CHIG students had a better grasp of the concepts involved and were more skillful in communicating their ideas in words.

Table 16 *Performance of the EMI and CHIG students on the free-response items*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
23	EMI	.500	.777	-1.029	0.001
	CHIG	1.529	.782		
24	EMI	.446	.636	-0.291	0.001
	CHIG	.737	.774		
25	EMI	.758	1.201	0.429	0.001
	CHIG	.329	.862		
Total score	EMI	1.705	1.752	-0.891	0.001
	CHIG	2.596	1.487		

Analysis of the student answers may provide some clues on the poorer performance of the EMI stratum. Of the three free-response questions, the EMI students out-performed the CHIG students in item 25 only, which requires a description of an experiment to show that there are spaces between liquid particles. This is a typical textbook experiment prescribed in the S1 science curriculum and is carried out by all students. Students could answer this question correctly by recall. Furthermore, many students used diagrams instead of words to describe the experiment. As there is less demand on language ability in answering this question, the EMI students would be less disadvantaged by their limited English proficiency.

The performance of the EMI students was significantly poorer than that of the CHIG students in the other two items. Item 23 asks for 'two ways in which animal cells differ from plant cells'. This seemingly straight-forward question requires the students to name a number of distinctive cellular structures. The poor performance of the EMI students can be related to the fact that many of them could not state the terms for the specific cellular structures in plant and animal cells, such as vacuoles, cell wall and chloroplasts, thus failing to give accurate and relevant answers as required.

Item 24 is concerned with drawing a conclusion about the general effect of heating on carbonates on the basis of the changes observed. This question requires the students to evaluate the results before making the generalization. Despite their higher initial academic ability, many of the EMI students just stated the conclusion for individual reactions without pointing out a trend or pattern for the reactions of carbonates. The much poorer performance of the EMI students in this item suggests that they were less capable of using high-level cognitive skills such as evaluation and synthesis than their CMI peers.

PERFORMANCE ON THE S3 SCIENCE ACHIEVEMENT TEST

1. Multiple comparison of the mean performance among the four school strata

The 99-Cohort attempted the S3 Science Achievement Test (Appendix 3) in April to June of 2002. Part A of the test contains 30 multiple-choice questions and Part B contains three free-response questions. The questions yield a satisfactory reliability with alpha value of 0.633. Table 17 shows the mean scores of the four school strata in this test and the analysis of variance of the mean scores among different school strata.

Table 17 *Mean scores of different school strata on the S3 Science Achievement Test and comparison of the means*

		EMI	CHIG	CMID	CLOW
N		4191	4198	3907	3492
Mean		45.03	46.06	40.67	35.84
Std. Deviation		11.10	11.52	12.26	12.96
Difference of the means	EMI	-	-1.03*	4.36*	9.19*
	CHIG	-	-	5.39*	10.23*
	CMID	-	-	-	4.83*

* The difference of the means is significant at the 0.001 level.

The results of the S3 science achievement follow a similar pattern as that of the S1 and S2 science achievement. The science achievement of the students of the CMI school strata (i.e. CHIG, CMID and CLOW) at the end of S3 were correlated with their prior academic abilities, with the mean test scores decreasing in the order of CHIG, CMID and CLOW. The EMI schools, on the other hand, performed slightly less satisfactorily than the CHIG schools, despite the higher pre-entry ability of their S1 students. Item analysis on the S3 science test is carried out below in order to identify the weakness of the EMI students in relation to the CMI students.

2. Item analysis of the multiple-choice and free-response questions

Of the total 30 multiple-choice questions in the S3 Science Achievement Test, three items have been deleted from the process of statistical analysis because they show very low or even negative discrimination index, i.e. below 0.2. These are Item 6 (extraction of iron from iron oxide), Item 20 (the most common non-metal element) and Item 25 (function of xylem). A possible reason for the low discrimination index of these items is that many schools might not have covered the topics concerned, as there is a lot of variation in the science curriculum adopted by schools at the S3 level. Some schools might still follow the official S3 science curriculum, but most schools would have incorporated different parts of the S4-5 curriculum for physics, chemistry and biology into the S3 science curriculum so as to prepare their students for the Certificate Examination at the end of S5.

(a) Multiple-choice items in which the EMI students out-performed the CHIG students

Out of the remaining 27 multiple-choice questions in the S3 Science Achievement Test, the EMI stratum performs better than the CHIG stratum in 10 items (i.e. items 4, 8, 11, 13, 15, 16, 17, 18, 24 and 30), at a level of significance of $p<0.001$ (Table 18).

Table 18 *Performance on multiple-choice items of the S3 Science Achievement Test in which the EMI students out-performed the CHIG students*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
4	EMI	.567	.496	0.094	0.001
	CHIG	.474	.499		
8	EMI	.386	.487	0.053	0.001
	CHIG	.333	.471		
11	EMI	.497	.500	0.061	0.001
	CHIG	.437	.496		
13	EMI	.235	.424	0.064	0.001
	CHIG	.171	.377		
15	EMI	.395	.489	0.065	0.001
	CHIG	.330	.470		
16	EMI	.848	.359	0.050	0.001
	CHIG	.798	.401		
17	EMI	.387	.487	0.059	0.001
	CHIG	.328	.469		
18	EMI	.397	.489	0.062	0.001
	CHIG	.335	.472		
24	EMI	.830	.375	0.077	0.001
	CHIG	.754	.431		
30	EMI	.425	.494	0.073	0.001
	CHIG	.352	.478		

The result suggests that the EMI students were less disadvantaged in these items by learning science through English, since they demonstrated a higher performance than their CMI peers. These items include those that assess understanding of basic scientific knowledge, such as asking for the mineral salts required by humans (Item 4), the excretory substance produced by body (Item 8), the chemical that gives a golden yellow flame (Item 11), and the use of sodium hydroxide (Item 13).

However, it is worth noting that the EMI students out-performed their CMI peers in a number of items that assess understanding of concepts that involve scientific terminology and the ability to apply scientific knowledge in everyday life contexts, e.g. Items 15, 16, 17, and 24. For instance, in answering Item 15, which asks for an efficient way for transmitting electricity, students need to master the concept of voltage and current in relation to the energy loss during electricity transmission. For Item 16, students have to relate the problem of night blindness to the knowledge of vitamin A content in common foodstuffs, which cannot be resolved by direct recall of textbook information. For Item 18, which is concerned with an integrated understanding of the structure of plant cells, students have to master the terminology of plant cells, such as epidermal cells, xylem cells and mesophyll cells, and of various cellular structures. For Item 24, which asks students to explain why a man can jump higher on the moon than on the earth, students have to possess a good understanding of the relationship between gravity and body mass. The better performance of the EMI students in these items is quite different from the findings obtained in the S1 and S2 tests, which show that the EMI students were less competent in the mastery of scientific terminology and application of science concepts as compared to their CMI counterparts.

(b) Multiple-choice items in which the EMI and CHIG students showed similar performance

There are 13 items for which the mean score of the EMI stratum is comparable to that of the CHIG stratum (Table 19), suggesting that the EMI students were slightly disadvantaged in such items.

Table 19 *Performance on multiple-choice items of the S3 Science Achievement Test in which the EMI and CHIG students showed comparable performance*

Item	Stratum	Mean	Standard deviation	Difference of the means
2	EMI	.449	.497	-0.024
	CHIG	.473	.499	
3	EMI	.574	.495	0.004
	CHIG	.570	.495	
5	EMI	.681	.466	-0.022
	CHIG	.702	.457	
7	EMI	.416	.493	0.011
	CHIG	.405	.491	
9	EMI	.437	.496	-0.022
	CHIG	.459	.498	
10	EMI	.159	.365	-0.021
	CHIG	.180	.384	
14	EMI	.495	.500	0.013
	CHIG	.482	.500	
19	EMI	.292	.455	-0.017
	CHIG	.309	.462	
21	EMI	.186	.389	0.018
	CHIG	.168	.374	
22	EMI	.745	.436	0.000
	CHIG	.745	.436	
26	EMI	.397	.489	0.016
	CHIG	.381	.486	
28	EMI	.693	.461	0.019
	CHIG	.674	.469	
29	EMI	.530	.499	-0.027
	CHIG	.558	.497	

Some of these items involve in-depth understanding of biological concepts, such as the identification of energy-rich food substances (Item 3), the knowledge of presence of urea and mineral salts in urine (Item 9), difference between arterial and venous blood (Item 19), the representation of parallel rays in a ray diagram of the eye (Item 21), the digestive organs in mammals (Item 23), and the reproductive features of different plant groups (Item 26). Some items are concerned with chemical concepts, such as the identification of rusting as a chemical change (Item 5) and the movement of ions in electrolysis (Item 10). One item is concerned with experimental design in which the students have to draw conclusions on the condition for onion germination by comparing two different set-ups that differ in one condition (Item 22).

(c) Multiple-choice items in which the CHIG students out-performed the EMI students

For the remaining four multiple-choice items, the CHIG students performed significantly better than the EMI students at a level of significance of $p<0.001$ (Table 20), suggesting that the EMI students were disadvantaged in these items.

Table 20 *Multiple-choice items of the S3 Science Achievement Test in which the CHIG students out-performed the EMI students*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
1	EMI	.453	.498	-0.055	0.001
	CHIG	.508	.500		
12	EMI	.618	.486	-0.056	0.001
	CHIG	.675	.469		
23	EMI	.676	.468	-0.039	0.002
	CHIG	.715	.451		
27	EMI	.589	.492	-0.120	0.001
	CHIG	.708	.455		

Some of these items might be more problematic to the EMI students because they involve the mastery of biological terms and names of chemicals in a second language, such as the distinction of different parts of a tooth (Item 1), the identification of the role of various chemicals in the prevention of tooth decay (Item 12), and the reactivity of different metals with oxygen (Item 27). Item 23 assesses in-depth understanding of investigative skills, as it requires students to conclude from a comparison of two experimental set-ups that light is not necessary for the germination of onion bulbs. The poorer performance of the EMI students, as compared to the CHIG students, suggests that they were less proficient in the concept of controlling variables.

(d) Performance on the free-response items

The overall performance of both the EMI and CHIG students on the free-response questions is less than satisfactory, particularly for Items 32 and 33 (Table 21).

Table 21 *Performance of the EMI and CHIG students on the free-response items of the S3 Science Achievement Test*

Item	Stratum	Mean	Standard deviation	Difference of the means	Significance level
31	EMI	1.443	.864	-0.208	0.001
	CHIG	1.651	.882		
32	EMI	.412	.519	-0.193	0.001
	CHIG	.605	.529		
33	EMI	.608	.872	-0.095	0.001
	CHIG	.703	.942		
Total score	EMI	2.464	1.442	-0.496	0.001
	CHIG	2.960	1.551		

Responses to Item 32 indicate that most students do not master the concept of force, and they tend to account for the slowing down of the bicycle to the lack of force rather than to resistance from air or friction. When some students mention friction as a retarding force on the movement of the bicycle, they often erroneously refer to the friction between the bicycle tyre and ground instead of between the moving parts of the bicycle. Item 33 is concerned with the nature of the bubbles formed when water is boiling. Only a small percentage of students pointed out correctly the bubbles are formed of steam. Most students give alternative explanations that are not consistent with the scientific view. A very common answer given is that the bubbles are formed by the air dissolved in water, probably due to muddling up with the experience that a lot of gas bubbles are evolved when a can of soft drink is opened. Another common alternative answer is that the bubbles are formed from hydrogen and oxygen which are the chemical components of water. These alternative conceptions suggest that the S3 students, irrespective of the medium of instruction used in science lessons, have difficulty in mastering abstract concepts in science and their lack of understanding is revealed when they are required to apply their learned subject knowledge to explain everyday life phenomena.

As in S1 and S2, the CHIG students show better performance than the EMI students on the free-response questions of the S3 Science Achievement Test. However, the difference in performance between the EMI and CHIG students is much smaller, indicating that the gap between these groups of students is getting narrower.

EFFECTS OF THE LANGUAGE OF TEST PAPER ON THE PERFORMANCE OF EMI STUDENTS

In the above discussion, the poorer performance of the EMI students in comparison with the CHIG students is attributed to the possible problems encountered by the EMI students in understanding the subject matter of science when they receive instruction in English. Although the questions in the achievement tests are constructed by experienced science teachers in simple English attuned to the language proficiency levels of the target students, there is, however, a possibility that the performance of some EMI students would be affected by the language used in the science achievement test. When the questions of the achievement test are written in English, students with a low proficiency in English may not be able to understand the meaning of the questions. In this case, the poor performance may have been caused by inadequate language ability rather than lack of understanding of science concepts.

In order to study the impact of test language on students' understanding or interpretation of written questions, two versions of the S2 Science Achievement Test had been prepared for the EMI students. As described in Chapter 3 (p.82), about one-third of the EMI students in each class were given a test paper written in English, while the rest attempted a bilingual paper.

With the data collected from these two versions of the test paper, we can split the science achievement scores of the EMI students into two parts according to the language versions of the test paper, and re-run the above models of sampling-strata effect. The results of the multi-level analyses of these models for the performance on the S2 Science achievement Test are presented in Appendix 6 and summarized in Table 22.

Table 22 *Effects of sampling strata on the S2 science achievement scores with two versions of test papers for the EMI students*

	Bilingual version	**English version**
Fixed effects		
Pupil level (L1)		
Intercept	0.176*	0.240*
AAI	0.553*	0.558
School level (L2)		
CHIG effects on mean scores	0.522*	0.839*
CMID effects on mean scores	0.313*	0.625*
CLOW effects on mean scores	0.521*	0.816*
Random effects		
% of L1 variance explained	7.76%	7.90%
% of L2 variance explained	71.53%	68.89%

* Significant at 0.05 level

The split-version models on science achievement produce some significant differences in sampling-strata effects. All the six coefficients of sampling-strata effects on science achievement are significant and positive in values (Table 22). When the magnitudes of the coefficients between the two language models are compared, the coefficient in the English-version model is larger than the corresponding value in the bilingual-version model by about 0.3 of a standard deviation. This means that the students in each of the CMI strata outperformed the EMI students who were tested with the English paper by a much larger margin (i.e. 0.3 of a standard deviation) than the EMI students tested with the bilingual paper. In other words, the EMI students performed more poorly on the English paper than on the bilingual paper. This observation suggests that the EMI students may experience problems in understanding certain questions in the achievement test when they are presented in English and consequently their performance is adversely affected. These problems are less serious with the bilingual paper, as the students can refer to the Chinese version when they fail to understand the meaning of a question written in English.

When setting the achievement test in English, the general level of English proficiency of the EMI students had been taken into consideration, and the test items were carefully constructed in simple English, avoiding the use of difficult vocabularies and complex sentence structure as far as possible. Nevertheless, the results indicate that some EMI students still lack the basic English proficiency that is necessary for understanding simple written English. It is very likely that such students will experience even greater difficulties in understanding science subject content when the lessons are conducted in English.

Even when a bilingual test paper is used, the performance of the EMI students is still significantly below that of the CMI students, after controlling for student AAI. This shows that the amounts of value-addedness in science achievement of the three CMI school strata far exceed that of the EMI stratum. This finding provides strong support for the previous conclusion that the EMI students are disadvantaged in science learning by their limited proficiency in English.

CONCLUSIONS

For the 1999 student cohort, analysis of variance reveals that the differences in mean scores in the S2 Science Achievement Test among the four school strata are all statistically significant. Among the CMI schools, the mean scores occur in descending order according to the sampling strata, i.e. CHIG > CMID > CLOW. Despite the higher mean AAI of the EMI stratum, the mean score of the EMI students is found to be statistically significantly lower than that of the CHIG students. In other words, the CHIG students demonstrated higher achievement in science than the EMI students in S2. Multi-level analysis also shows that all CMI strata substantially outperformed the EMI stratum in the S2 Science Achievement Test after controlling the school mean AAI. These findings indicate that using English as a medium of instruction has a potentially negative effect on science learning, and support the observations made in local studies (e.g. Johnson and Cheung, 1992; Johnson and Lee, 1987; Johnson and Yau, 1996) that the EMI students had not reached an adequate level of English proficiency for them to learn effectively through English. This conclusion regarding the negative effect of EMI on learning is valid for the junior secondary years in general, as similar results are obtained from the S1 and S3 Science Achievement Tests.

Comparison of the performance of the EMI and CMI students on individual test items provides some clues on the underlying causes for the lower science achievement of the EMI students, thus helping us to identify the possible problems associated with learning science in a second language. Item analysis of the S2 Science Achievement Test reveals that the EMI students out-performed the CHIG students only in a small number of multiple-choice items, which have relatively low cognitive demand. Despite their initial higher academic ability as reflected by the AAI scores, the performance of the EMI students in most multiple-choice items was similar to or less satisfactory than the CHIG students. These items mainly assess understanding of abstract concepts, terminology used in science, the nature of experimental design, and the ability to apply scientific knowledge in realistic or novel situations. All these require high level thinking and the mastery of the language of science.

These observations thus provide evidence that the EMI students experienced particular difficulties in mastering scientific terminology and developing higher cognitive skills and conceptual understanding of science subject matter, when compared with their CMI peers who learn science through their native language. As the medium of instruction is the key difference between the school setting of the EMI and CMI schools, a likely cause of the lower science achievement of the EMI students, relative to the CHIG students, is that their language proficiency was not good enough for them to learn science effectively in English. This "hurdle" in science learning as incurred by learning through a second language is also suggested by the much poorer performance of the EMI students in the free-response items, which demand deeper understanding and better communication skills than the multiple-choice items. These findings do not support the assumption made in the *Guidance* that students of EMI schools are capable of learning effectively through English.

To appreciate the difficulties encountered by the EMI students, we should bear in mind that these students experienced a sudden change in the medium of instruction from their native language to a second language when they began their secondary education. Throughout their primary education, most EMI students had been instructed in their mother tongue, Chinese, whereas English was only taught as a single subject. While the EMI students were academically more able than the CMI students at the end of primary schooling, they might not have attained a standard in English language skills that was proficient enough for them to receive instruction and to communicate in English. This view is substantiated by the findings of some local studies. For example, in a study designed to compare achievements in Chinese and English using tests from the International Association for the Evaluation of Educational Achievement, Johnson and Cheung (1992) showed that S3 students (15 years olds) had a lower standard of reading in English than in Chinese. In another study, Johnson and Lee (1987) showed that about a third of S3 students scored little above what could be achieved by chance on tests of listening and reading in English, and that for the same student cohort, the best scores on the English tests were equivalent to the lowest scores on the Chinese tests. Even after 7 years of immersion in English, S7 students demonstrated much better reading skills in Chinese than in English (Johnson and Cheung, 1995). As Hong Kong students in general achieve a much lower standard in English than in Chinese, it is expected that the EMI students will be negatively affected in their learning despite their higher prior ability, at least in the initial years of immersion in English in secondary schooling.

Thus, when students learn science in a second language that they have not yet mastered, they would be placed at a distinct disadvantage relative to those that learn in the first language. This implication is supported by the findings on students' performance on the science achievement tests in this study. It may be that, for instance, teachers in EMI schools are seriously constrained in what they can present to their students, and the EMI students may not be able to understand complex concepts in English. Furthermore, some teachers may not be able to present the lesson content fluently and coherently in English. While most EMI students can master concrete concepts, their ability to construct, apply and present the more abstract and complex scientific ideas in English is frustrated by their limited language proficiency (Willig, 1985). These problems of learning science in a second language have been reported in a number of late immersion programmes (e.g. Marsh *et al.*, 2000; Met and Lorenz, 1997; Swain and Johnson, 1997).

The above analysis and conclusions lead to further questions on the impact of the medium of instruction on science learning:

1. What are the effects of MOI on the instructional activities in science lessons? Can these effects account for the difference in science achievement between the EMI and CMI students?
2. Is the constraint in science learning experienced by the EMI students transitory or long lasting?
3. Will the gap in science achievement between the EMI and CHIG students be narrowed down after a number of years as the EMI students become more proficient

in English or more used to receiving instruction in the second language?

4. Will the gap between the EMI and CMI students be widened as the cognitive demand of the science curriculum increases in higher secondary levels?

To seek answers to these questions, an important element of the present study is explore and identify the causes that may have led to the differential science achievement of the EMI and CMI students. To do this, we need to study the characteristics of science lessons as conducted in the EMI and CMI schools. The classroom climate and nature of instructional activities will have direct impact on the process of learning. When conducting the S2 Science Achievement Test, the students were asked to respond to a questionnaire of 16 items, some of which are concerned with their perception of the classroom climate of science lessons (Chapter 3, p.86). The responses on these items can provide useful information on the effects of MOI on the processes of learning and teaching, such as the pedagogical styles of the science teachers and the types of activities carried out during science lessons. Observation of science lessons (Chapter 3, p.88-89) can also help us understand the realism of classroom contexts in EMI and CMI schools and compare these classrooms in relation to the different media of instruction used. Other items of the questionnaire explore students' self-concept in science, which is another important outcome of the learning process. These items contribute to identifying the effects of MOI on students' motivation and interest in learning science, and their self-esteem and self-confidence in school science.

Thus through the analysis of the student questionnaire and classroom observation, we can obtain some insights into the constraints and problems of adopting English as a medium of instruction for science in the early years of secondary schooling in Hong Kong. Such information will hopefully guide the development of appropriate strategies for implementing the MOI policy for the EMI schools, so that their students can have a smooth and efficient transition from CMI to EMI for the effective learning of science and other content subjects through a second language. The effects of MOI on the students' self-concepts in science are explored in Chapter 5, while the effects of MOI on the instructional activities in science lessons are discussed in Chapter 6.

We can also compare the growth in science achievement between the EMI and CMI students of the 99-Cohort through S1 to S3, to see whether there is any change in the difference in science achievement among the four school strata with increase in time of exposure to the new MOI policy. These data will be reported in Chapter 7.

CHAPTER 5

THE EFFECTS OF MEDIUM OF INSTRUCTION ON STUDENTS' SELF-CONCEPT IN SCIENCE

This chapter reports the effects of MOI on students' self-concept in science, which is based on students' responses on specific items on the student questionnaire. It starts with a general comparison of students' self-concepts of the four sampling strata of the 99-Cohort in four school subjects. The purpose is to see whether the effects of MOI on the formation of science self-concept are comparable to those on other academic self-concepts. This is followed by an analysis of the responses to different items of the questionnaire on science self-concept and a discussion of the implications of the findings.

SELF-CONCEPTS IN SCIENCE AND OTHER SUBJECTS

When the 99-Cohort worked on the S2 achievement tests on various school subjects in April-June of 2001, they also attempted the student questionnaire with items assessing their self-concepts in individual academic subjects (Chapter 3, p.85). Responses to these items have generated four dimensions of self-concepts. They are the self-concepts in Chinese, English, Mathematics and Science. Analysis of the difference of the means is conducted to study whether there are any significant differences in these four measures of self-concept among the four school strata of the 99-Cohort, and the results are presented in Table 23.

Table 23 *Analysis of variance of academic self-concepts among sampling strata of the 99-Cohort in the academic year 00/01*

		Overall	EMI	CHIG	CMID	CLOW
Chinese	N	16197	4422	4233	3842	3700
	Mean self-concept	3.16	3.28	3.16	3.13	3.06
	Std. Deviation	0.64	0.66	0.63	0.62	0.62
	Mean Difference	EMI	-	0.115*	0.147*	0.213*
		CHIG	-	-	0.032	0.098*
		CMID	-	-	-	0.066*
English	N	16197	4422	4233	3842	3700
	Mean self-concept	2.68	2.90	2.67	2.63	2.48
	Std. Deviation	0.74	0.70	0.73	0.75	0.75
	Mean Difference.	EMI	-	0.229*	0.264*	0.413*
		CHIG	-	-	0.035	0.184*
		CMID	-	-	-	0.149*
Mathematics	N	17192	4681	4430	4064	4017
	Mean self-concept	2.953	3.12	3.00	2.85	2.81
	Std. Deviation	0.893	0.85	0.89	0.90	0.91
	Mean Difference.	EMI	-	0.116*	0.267*	0.307*
		CHIG	-	-	0.151*	0.191*
		CMID	-	-	-	0.040
Science	N	17421	4714	4544	4093	4070
	Mean self-concept	2.62	2.58	2.66	2.61	2.62
	Std. Deviation	0.50	0.49	0.49	0.52	0.50
	Mean Difference	EMI	-	-0.086*	-0.038*	-0.045*
		CHIG	-	-	0.048*	0.041*
		CMID	-	-	-	-0.007

* The mean difference is significant at the 0.05 level.

For Chinese, English and mathematics, the differences in self-concepts between students in the EMI and CMI schools are quite consistent in that the EMI students hold higher academic self-concepts than the students in the three CMI strata. The differences in self-concept means between the EMI students and the students of the CHIG, CMID and CLOW schools are all positive and statistically significant. Among the three strata of CMI schools, the mean self-concepts descend in the order of CHIG, CMID and CLOW, and most of the mean-differences are statistically significant. A possible explanation for this consistent pattern of academic self-concepts in Chinese, English and mathematics among the four school strata is that the academic achievement has a positive effect on the formation of self-concept in specific subject areas, a relationship that has been reported in a number of studies (e.g. Marsh *et al*, 1988; Marsh *et al.*, 2001; Skaalvik and Hagtvet, 1990). Based on the 99-Cohort students' performance on various achievement tests, it has been demonstrated that the EMI students out-performed the students of the three CMI strata in English, Chinese and mathematics (Tsang, 2002). It follows that the EMI students would form a higher self-esteem in these subjects, despite the fact that they are under more intense competition with their peers in the school. The same reasoning can account for the differences in mean scores for science self-concept among the CHIG, CMID and CLOW schools.

The higher value of mathematics self-concept of the EMI students over the CMI students also suggests that learning mathematics in a second language has little negative effect on the formation of academic self-concept by the EMI students. This may be due to the fact that learning mathematics does not require a high level of proficiency in the language of instruction. Thus although the English proficiency of the EMI students is lower than their proficiency in Chinese, they do not appear to be disadvantaged in acquiring mathematics concepts through English instruction.

The scores on the self-concept in science among the three CMI strata show a similar pattern which support the finding from research that academic achievement has a positive effect on the formation of self-concept (Chapter 2, p.59-61). The CHIG students have a higher self-concept in science than the CMID and CLOW students, and the differences of the means are statistically significant. The mean values of science self-concept of the

CMID and CLOW students are, however, comparable to each other.

In contrast to the pattern observed for Chinese, English and mathematics, the EMI students showed a lower self-concept in science than the CMI students. Despite their higher prior academic ability, the mean value of the science self-concept of the EMI students is lower than those of the CHIG, CMID and CLOW students, and the differences in means between the EMI and the three CMI strata are all statistically significant. An interpretation for the lower science self-concept of the EMI students is that these students may have been disadvantaged by the medium of instruction in science learning. This explanation is consistent with the relatively poorer performance of the EMI students on the Science Achievement Tests reported in Chapter 4. Science learning involves the mastery of a language and terminology that are unique to science, and the understanding and internalization of abstract ideas. These requirements impose a high demand on the language proficiency as well as the cognitive ability of the students. Because of the high demand on abstract thinking and of the language of science, many children experience difficulties in understanding science subject matter when they learn science through their mother tongue (Garraway, 1994; Gonzalez, 1998; Rollnick, 2000). These problems become more acute when a second language is used as the medium of instruction. Thus the EMI students are doubly challenged with the need to master both science content and a second language. To understand how various factors may contribute to the formation of science self-concept in various school strata, it is necessary to analyse the responses to individual items of the questionnaire.

Based on the responses of the 99-Cohort students to the student questionnaire, the mean scores of individual items on science self-concept of the four school strata are computed. Analysis of variance between the differences of the means is summarized in Table 24.

Table 24 *Analysis of variance of science self-concept items among sampling strata of the 99-Cohort in the academic year 00/01*

		Overall	EMI	CHIG	CMID	CLOW
Item 1	Mean	2.39	2.30	2.47	2.40	2.41
	Std. Deviation	0.74	0.71	0.73	0.75	0.76
Mean Difference	EMI		-	-0.180*	-0.100*	-0.110*
	CHIG		-	-	-0.072*	-0.067*
	CMID		-	-	-	-0.005
Item 2	Mean	2.54	2.44	2.58	2.55	2.59
	Std. Deviation	0.69	0.67	0.68	0.69	0.71
Mean Difference	EMI		-	-0.150*	-0.120*	-0.150*
	CHIG		-	-	0.028	-0.009
	CMID		-	-	-	-0.037*
Item 3	Mean	2.75	2.83	2.75	2.72	2.72
	Std. Deviation	0.77	0.72	0.76	0.79	0.81
Mean Difference	EMI		-	0.079*	0.100*	0.110*
	CHIG		-	-	0.024	0.028
	CMID		-	-	-	0.004
Item 4	Mean	2.80	2.88	2.80	2.76	2.75
	Std. Deviation	0.76	0.70	0.73	0.78	0.81
Mean Difference	EMI		-	0.084*	0.120*	0.140*
	CHIG		-	-	0.039*	0.055*
	CMID		-	-	-	0.157
Item 5	Mean	2.44	2.54	2.37	2.41	2.41
	Std. Deviation	0.80	0.78	0.77	0.81	0.84
Mean Difference	EMI		-	0.170*	0.130*	0.130*
	CHIG		-	-	-0.045*	-0.041*
	CMID		-	-	-	0.005
Item 6	Mean	2.46	2.30	2.57	2.51	2.49
	Std. Deviation	0.79	0.74	0.76	0.80	0.82
Mean Difference	EMI		-	-0.270*	-0.220*	-0.200*
	CHIG		-	-	0.052*	0.072*
	CMID		-	-	-	0.020
Item 7	Mean	2.82	2.83	2.88	2.78	2.80
	Std. Deviation	0.72	0.68	0.68	0.75	0.76
Mean Difference	EMI		-	-0.052*	0.052*	0.028
	CHIG		-	-	0.100*	0.081*
	CMID		-	-	-	-0.024

Items 1 and 2 elicit students' perception of their ability in science. Item 1 ("*My achievement in the science subject is better than that in other subjects.*") asks the students to compare their performance in science with that in other subjects. The mean scores of the four school strata all cluster around the middle value, ranging from 2.30 to 2.47. While the CHIG students have a higher mean score than the students of the other two CMI strata, the score of the EMI students is lower than those of the students of the three CMI strata, and the differences in means are all statistically significant. Item 2 ("*My performance in the science subject is always good.*") estimates students' confidence in school science. The scores on Item 2 are very similar to those on Item 1, clustering around the middle value ranging from 2.44 to 2.59. The EMI students also show a significantly lower perceived ability in science than the students of the three CMI strata.

Taking these two items together, it is evident that the EMI students had formed a lower self-concept in science than the CMI students, including the CLOW students who are academically much less able. This observation appears to be contradictory to the well-founded finding that achievement has a positive effect on self-concept. The discrepant effect observed on the formation of science self-concept of the EMI students in this study can be related to the medium of instruction used. A possible explanation is that the EMI students may experience greater difficulty in learning science through English than the CMI students who learn science in their mother tongue. The difficulty may lie in the large amount of new terminology required in learning science and the high cognitive demand in understanding abstract science concepts, as discussed in the analysis of the performance on science achievement tests (Chapter 4). These innate difficulties in science learning would be particularly demanding and challenging for the EMI students, who have to cope with these challenges in a language that they are less proficient with.

The next two items ask students whether they like science (Item 3) or find science interesting and challenging (Item 4). For both items, the mean scores of the EMI students are higher than those of the students of the three CMI strata, and the differences of the means between the EMI and CMI strata are all statistically significant. These results suggest that the EMI students are more academically oriented than their CMI peers, and they like the challenges in learning science despite the fact that they have additional challenges when learning the subject through a second language. Among the CMI schools, however, the mean scores of all three strata for Item 3 (*I like attending science lessons.*) are comparable with no statistically significant differences between them, whereas the CHIG students find science more interesting and challenging than the CMID and CLOW students do (Item 4).

Item 5 is concerned with students' perception of the nature of science subject ("*I think that science subject demands a lot of memory work.*"). The mean score of the EMI students is higher than those of the three CMI strata, and the differences of means between the EMI students and the CHIG, CMID and CLOW students are all statistically significant. This difference in perception can be related to the different media of instruction used in teaching and learning science. Learning science involves understanding of special scientific terms and abstract concepts, which could pose problems for students who learn science in their mother tongue. These problems are even more challenging for students who have to learn science in a second language. With problems in understanding and in expressing scientific ideas in English, EMI students may have to resort to memory as a strategy for studying science so that they can recall scientific information in examination situations. This assertion is substantiated by the observation that the EMI students performed better on recall-type items than items that require higher cognitive skills in the science achievement tests. This learning strategy is probably less necessary to the CMI students, because they can understand better when science lessons are conducted in Chinese.

This explanation is supported by the responses to Item 6 ("*I think that the science subject is easy.*"). The mean score of the EMI students on this item is much lower than those of the students in the three CMI strata, whereas among the CMI schools, the mean scores are positively related to students' general ability, decreasing in the order of CHIG, CMID and CLOW. A well-documented problem of learning science in a second language such as English is that students experience great difficulty in understanding the science texts in terms of vocabulary, sentence structure and style (MacDonald, 1990; Ryf and Cleghorn, 1997; Tendencia, 1999). The expository nature of the science texts is particularly inaccessible to second-language learners, especially for those that have a low proficiency in English. The relative low score of the EMI students in this item suggests that the problem of understanding science texts in a second language is also experienced by these students, despite the fact that they are academically more able than their CMI peers, and in theory should have achieved adequate levels of English proficiency through their primary schooling.

The responses to Item 7 ("*I understand the explanation of my science teacher.*") are consistent with above interpretation. Among the CMI schools, the mean scores are positively related to students' general ability, whereas the EMI students indicate greater problems in understanding teachers' explanation than the CHIG students. In the Science Achievement Test, item analysis reveals that the EMI students performed less satisfactorily than the CHIG students in items that require applications of scientific knowledge in realistic and novel situations, an ability that is basically founded on understanding and internalization of science concepts.

CONCLUSIONS

According to the responses to Items 1 and 2 of the student questionnaire, the EMI students show a lower self-concept in science than their CMI peers, despite the fact that they are socially recognised as an elite class among their peers. They have higher AAI scores than the students of all CMI strata and they have actually scored better than the CMID and CLOW students in the Science Achievement Tests. This is quite different from the relatively high self-concept of the EMI students in other subjects, such as Chinese, English and mathematics.

To identify the causes for the relatively low science self-concept of the EMI students, the relationship between the process of self-concept formation and the medium of instruction is explored. Analysis of performance on the Science Reasoning Tests reveals that the EMI students, in comparison with the CHIG peers, are weaker in the mastery of abstract concepts, application of scientific knowledge to realistic or novel situations and use of scientific terminology. These problems can be accounted for and related to the use of English instead of the mother tongue as the medium of instruction in science lessons. Although the EMI students demonstrate higher prior ability and are more proficient in English, the high language demand for making sense of science texts and instruction, and for understanding and internalization of abstract and complex science concepts makes science learning particularly difficult for second language learners. This explains why the self-concept of the EMI students in science is lower than that in mathematics, which makes far less demand on the language proficiency of the learners. This is reflected in the particularly low score of the EMI students on Item 1 of the student questionnaire, which asks the students to compare their perception of achievement in science with that in other school subjects.

The scores on Items 3 and 4 indicate that the EMI students are more academically oriented than the CMI students, but they experience greater problems in learning science through a second language. It may be that it is more difficult for them to fully understand new scientific terms that are rich in special meanings, the meaning of abstract concepts that are constructed from scientific terms, and the logical synthesis of complex ideas from basic concepts. These problems related to the learning of science in a second language is consistent with the lower mean score of the EMI students for Item 7 in comparison with that of the CHIG students, which indicates that the EMI students perceived greater difficulty in understanding teacher instruction. Consequently, the EMI students perceive that science is more difficult to learn than the CMI peers do, as is reflected by the particularly low score of the EMI students for Item 6. Because of the problems in understanding, the EMI students may have a greater tendency to resort to rote learning as an expedient strategy for passing examinations and tests (Llewellyn *et al.*, 1982: p.26-27; Johnson and Yau, 1996). This view is supported by the students' responses to Item 5, which indicate that the EMI students consider memory work as more important in science learning than the CMI students do.

Based on the responses to the science self-concept items, it can be concluded that the EMI students have a lower self-concept in their ability in science than the CMI peers. The EMI students perceive science as a difficult subject as they find it difficult to understand teachers' instruction through a second language and many of them may have to resort to rote learning as a strategy for acquiring science subject contents. According to the reciprocal effects model in which prior achievement affects subsequent academic self-concept and prior academic self-concept affects subsequent achievement (Marsh, 1993), an important implication of the present finding is that the low science self-concept of the EMI students will have a negative effect on subsequent science achievement. Furthermore, as students proceed to higher levels, science learning through a second language will impose more problems to the EMI students as the science curriculum includes more abstract and complex concepts. It can be anticipated that the science achievement of these students at higher levels will be even more adversely affected unless there is crucially adequate provision to enhance the development of their English proficiency and better support for science teachers, such as workshops on skills and strategies for teaching science through a second language. All these implications must be taken into consideration in the design and implementation of language policy for Hong Kong schools.

CHAPTER 6

THE EFFECTS OF MEDIUM OF INSTRUCTION ON THE INSTRUCTIONAL ACTIVITIES IN SCIENCE LESSONS

INTRODUCTION

Little research has been done on the effects of the medium of instruction on the styles of teaching and learning in Hong Kong classrooms. For the small number of studies reported (e.g. Johnson and Yau, 1996; Shek *et al.*, 1991), they are mainly concerned with late immersion classrooms of the EMI schools before the implementation of the new language policy in 1998. In many secondary schools that claimed to use EMI before 1998, English was used for the textbooks, notes, and all kinds of written work such as students' reports, tests and examinations, but a wide variation in the proportions of English to Cantonese were used in classroom instruction amongst schools, amongst teachers and amongst lessons taught by the same teachers (Johnson, 1983). Even in schools with the most able students, teachers in general used no more than 50% English for classroom instruction, while in schools that took in the less able students, teachers often used less than 10% English inside the classroom (Hirvela and Law, 1991; Shek *et al.*, 1991). According to research studies reviewed in Chapter 1 (p.5) and Chapter 2 (p.38-39), due to the limited English proficiency of the EMI students and of some teachers, the practice of mixed code instruction in many EMI schools was considered to be appropriate or even inevitable by teachers. This practice, however, as has been previously discussed, has negative effects on the development of English proficiency and the learning of content subjects.

The implementation of the new language policy in 1998 is an attempt by the government to resolve this problem. This policy assigns only students with adequate levels of English proficiency into EMI secondary schools and the rest into CMI schools (Chapter 1, p.13-14). It also demands schools to observe strictly the medium of instruction, and the practice of code switching in the classroom is prohibited.

Under the new language policy, it is expected that the elite group of EMI students, through complete immersion in English, can learn their subject matter in science effectively in a second language, while the CMI students can master their subject matter through instruction in their mother tongue. One way to assess the validity of this expectation is to compare the modes of instructional activities in science lessons between the EMI and CMI students. Such a study will lead to an understanding of the processes of learning gone through by these two streams of students that contribute to their differential learning outcomes. In the present study, data in this aspect are obtained from two sources: by a questionnaire on students' perception of classroom climate in science lessons, and by direct observation of science lessons.

STUDENTS' PERCEPTION OF CLASSROOM CLIMATE IN SCIENCE LESSONS

In the student questionnaire, Items 8-16 assess students' perception of classroom climate in science lessons (Chapter 3, p.86). By comparing the responses of EMI and

CMI students on these items, it may be possible to identify the effects of the medium of instruction on the interaction between the teacher and students in science lessons. The analysis of variance of students' perception among the four different school strata is summarised in Table 25.

The mean score of the EMI students on Item 8 ("*Students listen to teachers' explanation of subject content.*") is higher than those of the students of the three CMI strata, and the differences of the means are all statistically significant. Accordingly, the EMI students perceive that more lesson time is spent on receiving instruction from the teacher than their CMI peers do. An implication from this observation is that the EMI students may be more attentive in lessons so that the teachers can focus more time on teaching. This may be related to the fact that these students, having a higher prior ability in general, are academically more motivated. This implication is, however, not consistent with the responses to item 12 ("*Teacher manage classroom order.*"), as there is no significant difference between the time spent by teachers in controlling class discipline as perceived by the EMI and CHIG students. The mean score of CMID students is even lower than that of the EMI students, and the difference is statistically significant. This indicates that, according to the perception of the EMI students, more time spent on listening to teachers' explanation does not necessarily imply that they are more attentive during lessons than their CMI peers. This argument can be verified by data obtained from classroom observations that will be discussed in a later section.

Table 25 *Analysis of variance of students' perception of of instructional activities in science lessons among the sampling strata in academic year 00/01*

		Overall	EMI	CHIG	CMID	CLOW
Item 8: *Students listen to teachers' explanation*	Mean	3.29	3.40	3.33	3.21	3.23
	Std. Dev.	0.78	0.71	0.75	0.81	0.82
Difference of the mean	EMI		-	0.07*	0.19*	0.17*
	CHIG		-	-	0.13*	0.11*
	CMID		-	-	-	-0.02
Item 9: *Teachers ask students questions*	Mean	3.15	3.17	3.16	3.10	3.16
	Std. Dev.	0.77	0.73	0.74	0.79	0.81
Difference of the mean	EMI		-	0.01	0.08*	0.01
	CHIG		-	-	0.06*	0.00
	CMID		-	-	-	-0.06*
Item 10: *Students ask teachers questions*	Mean	2.82	2.80	2.78	2.80	2.93
	Std. Dev.	0.80	0.78	0.79	0.81	0.83
Difference of the mean	EMI		-	0.02	0.00	-0.13*
	CHIG		-	-	-0.02	-0.15*
	CMID		-	-	-	-0.13*
Item 11: *Students conduct group discussion*	Mean	2.57	2.57	2.59	2.62	2.49
	Std. Dev.	0.95	0.94	0.95	0.96	0.96
Difference of the mean	EMI		-	-0.023	-0.05*	0.08*
	CHIG		-	-	-0.02	0.10*
	CMID		-	-	-	0.13*
Item 12: *Teachers manage classroom order*	Mean	3.17	3.16	3.19	3.13	3.20
	Std. Dev.	0.77	0.72	0.73	0.80	0.81
Difference of the mean	EMI		-	-0.02	0.03*	-0.04*
	CHIG		-	-	0.05*	-0.02
	CMID		-	-	-	-0.07*
Item 13: *Students watch teachers' demonstration*	Mean	3.28	3.36	3.25	3.22	3.27
	Std. Dev.	0.71	0.63	0.68	0.74	0.78
Difference of the mean	EMI		-	0.11*	0.14*	0.09*
	CHIG		-	-	0.03*	-0.02
	CMID		-	-	-	-0.05*
Item 14: *Students follow instruction of manual*	Mean	3.16	3.22	3.18	3.13	3.10
	Std. Dev.	0.85	0.83	0.81	0.85	0.89
Difference of the mean	EMI		-	0.04*	0.09*	0.12*
	CHIG		-	-	0.05*	0.08*
	CMID		-	-	-	0.03
Item 15: *Students design procedure of experiment*	Mean	2.00	1.84	2.08	2.05	2.05
	Std. Dev.	0.91	0.82	0.88	0.92	0.98
Difference of the mean	EMI		-	-0.24*	-0.21*	-0.21*
	CHIG		-	-	0.03	0.03
	CMID		-	-	-	-0.01
Item 16: *Teachers check answers on work sheets*	Mean	3.21	3.25	3.24	3.19	3.15
	Std. Dev.	0.80	0.75	0.77	0.81	0.88
Difference of the mean	EMI		-	0.01	0.06*	0.10*
	CHIG		-	-	0.05*	0.09*
	CMID		-	-	-	0.04*

A different interpretation of the higher mean score of the EMI students on Item 8 is that a more didactic, teacher-centred approach is used for science teaching in the EMI schools. There is some support for this interpretation from the students' responses to Items 11 and 15, which are concerned with the prevalence of teacher-centred activities in science lessons. According to the mean scores on Item 11 (*"Students conduct group discussion."*), the extent to which students engage in group discussion is less in the EMI schools than in the CHIG and CMID schools. This observation suggests that the EMI students are less likely to participate in interactive learning activities.

The EMI and CMI schools show more substantial differences in the nature of practical work undertaken by the students as measured by Item 14 (*"Students follow the instruction of manual to conduct experiments."*) and Item 15 (*"Students design the experimental procedures by themselves."*). The mean score of the EMI students on Item 14 is higher than those of the CMI peers and the differences of the means are all statistically significant, indicating that the EMI students follow the laboratory manuals to a greater extent when performing practical work. Concomitantly, they have less chance to apply their scientific knowledge and use their own creativity to design investigations by themselves.

This implication is supported by the fact that the mean score of the EMI students on Item 15 is exceedingly low, and is significantly lower than the mean scores of the CHIG, CMID and CLOW students. The much higher mean score of the EMI students on Item 13 (*"Students watch teachers' demonstration in the laboratory."*) also suggests that the practical activities undertaken by the EMI students are more teacher-centred in nature, as they tend to spend more time watching teachers' demonstration in the laboratory than their CMI peers.

Implications

Two implications can be drawn from the above analysis about the possible impact of medium of instruction on instructional activities in science lessons. The first implication is that in the English-medium schools, science instruction tends to follow a more didactic approach to teaching, as the EMI students perceive that they spend more time than their CMI peers in listening to teachers' explanation, watching teachers' demonstrations and following teachers' manuals when performing experiments. On the other hand, they have less chance to engage in interactive learning activities such as group discussion, or in more creative practical work in which they can initiate or design their own investigations, as well as develop their language skills.

The more teacher-centred approach to science teaching in the English-medium schools is understandable in view of the problems encountered by the EMI students in learning science through a second language. Because of their limited English proficiency, the EMI students may find it more difficult to understand abstract and complex concepts, to express their ideas freely, or to present their arguments systematically during class. The problem of communication through a second language tends to discourage the use of interactive activities by the teacher in science learning. Instead, the teacher would favour the use of a didactic style in which the teacher plays the central role of transmitting knowledge, while the students serve as passive recipients of knowledge.

The second implication is that in the EMI schools, practical work tends to be conducted in a more traditional manner with the students following procedures prescribed in laboratory manuals. The CMI students perceive themselves to have more opportunities to design the methods of investigation, a task that demands creativity and high-order skills. This difference in the nature of practical work carried out in the EMI and CMI schools can also be attributed to the medium of instruction used. Despite the higher prior abilities of the EMI students, they may find it more difficult to engage in high order thinking through a language that they are less proficient with. As a result, the practical work planned by their teachers is restricted to stereotypic experiments that make less demand on the use of good communication skills and high-order cognitive skills.

A note of caution is appropriate at this point about the conclusions drawn from data based on a survey of perceptions. In forming their perceptions of instructional activities, as noted in Chapter 3 (p.79), students must evaluate their science lessons in relation to some standards or frames of reference, which may be affected by a variety of factors such as individual students' academic abilities relative to their peers or other external standards, their achievements and interests in science and other school subjects, the learning climate of the class or the school and their teachers. The perceptions will differ if students have different frames of reference. This inherent element of subjectivity associated with the formation of perceptions must be taken into consideration when interpreting the above implications derived from the present survey. This survey provides us with a picture of instructional activities that occur in science lessons as seen in the eyes of students instructed under different medium of instruction. However, to satisfy reliability and validity factors, this picture must be supplemented by other sources of information such as that obtained from classroom observations.

CLASSROOM OBSERVATION OF INSTRUCTIONAL ACTIVITIES IN SCIENCE LESSONS

As pointed out in Chapter 3 (p.88), five EMI and five CMI science lessons were selected for observation. Classroom observation in this study aims at collecting first-hand information about instructional activities beyond perception-based data. With this method, a better understanding is gained of the interactions and activities taking place in science lessons of different MOI streams. This understanding may help to explain the differential outcomes of science learning of the EMI and CMI students as reported in Chapters 4 and 5.

Because of the small number of selected classes observed and these classes might not be representative of the different streams of schools, no statistical analysis is made on the scores of the items assessed. This part of the study is qualitative in nature, being complementary to the quantitative study on students' perception of classroom climate (Chapter 3, p.86), and frequent reference will be made on the actual classroom activities observed to illustrate the possible impact of the medium of instruction on science lessons.

Table 26 *Item scores of the Science Lesson Evaluation Guide for the observed science lessons*

	Lessons observed											
	EMI schools						CMI schools					
	E-1	E-2	E-3	E-4	E-5	Mean score	C-1	C-2	C-3	C-4	C-5	Mean score
Teaching style:												
1. Pupils listen to teacher's explanation/instruction	5	5	5	4	4	4.60	4	3	3	4	3	3.40
2. Teacher shows continuous attention and motivation	2	3	4	3	4	3.20	4	4	3	4	4	3.80
3. Teacher checks answers on worksheet with pupils	-	-	-	4	4	4.00	-	2	3	3	-	2.67
4. Pupils attentive and keen	3	4	4	4	4	3.80	4	4	3	4	4	3.80
5. Pupils ask questions on lesson content	1	1	1	1	1	1.00	2	3	2	2	3	2.40
6. Use of interactive activities	1	1	1	1	1	1.00	1	1	2	1	3	1.60
Questioning skills:												
7. Teacher asks questions on recall	4	3	2	2	3	2.80	3	3	2	3	3	2.80
8. Teacher asks questions to assess understanding	2	1	1	1	1	1.20	3	5	2	4	4	3.60
9. Teacher asks high-order questions	2	1	1	1	2	1.40	3	3	2	3	3	2.80
10. Use of probing to improve pupils' responses	2	1	1	1	1	1.20	2	4	2	4	4	3.20
11. Pupils give long, thoughtful responses to questions	1	1	1	1	1	1.00	2	2	2	3	3	2.40
12. Pupils respond actively to questions	1	1	1	1	1	1.00	3	3	3	3	4	3.20
Communication skills:												
13. Language of teacher suitable and accurate	3	4	3	4	4	3.60	5	5	4	5	5	4.80
14. Quality of explanations of teacher	3	4	2	3	3	3.00	4	4	3	4	4	3.80
15. Mobility of teacher in classroom	2	2	2	3	3	2.40	3	3	3	3	3	3.00
16. Teacher watchful on all parts of classroom	2	3	3	4	3	3.00	3	4	3	4	4	3.60
17. Teacher energetic and enthusiastic	3	4	3	3	3	3.20	4	3	3	4	4	3.60
18. Interaction among pupils during discussion/practical	2	3	3	4	3	3.00	3	4	4	3	4	3.60

Scoring: 1 = rarely/weak, 3 = occasionally/satisfactory, 5 = always/good

Each lesson was assessed by two university science educators using the Science Lesson Evaluation Guide (Chapter 3, p.80), based on either direct classroom observation or videotaped lessons. A single score was awarded to each item on the Guide after discussion between the two assessors. The summary of scores on the 18 items of the Guide (Table 26) may provide some preliminary information about the nature of classroom climate and interaction in science lessons. However, caution must be exercised when making interpretation from these scores, as the lessons selected may not be representative of the school strata under study, and the classroom climate may be strongly affected by a variety of uncontrolled factors, such as the learning styles of the students, the skills and beliefs of individual teachers, and the nature of the subject matter covered by the lessons.

1. Teaching style

Teaching styles have important bearing on the outcomes of learning. In the traditional approach of science teaching, the teacher is mainly concerned with transmitting established knowledge and algorithms to students. It is assumed that understanding of scientific principles and their relationships will occur naturally after students have memorised a critical mass of facts (Lemberger *et al.*, 1999; Tobin and Gallagher, 1987). However, this teaching style does not lead to effective and meaningful learning, as knowledge thus acquired is fragmentary and easily forgotten, and is not readily transferable to realistic or novel situations.

According to research on learning, effective and meaningful learning occurs when the learner actively constructs knowledge by using existing knowledge to make sense of new experiences, so that the new concept forms part of the cognitive structure of the learner (Anderson, *et al.*, 1990; Gunstone, 1995; Posner *et al.*, 1982). To achieve meaningful learning in science, it is necessary to use interactive teaching styles that encourage students to express their views and ask questions, and promote a learning culture based on discussion and other student-centred activities.

In the analysis of science achievement of different school strata in Chapter 4, EMI students are found to perform less satisfactorily on items that require higher cognitive skills than the CHIG students. In order to account for this differential learning outcome in science, it is useful to examine and compare the teaching styles of the EMI and CMI science teachers as detected in the classroom observations of this study.

Based on the data reported in Table 26, an overall review of the scores for the items on *'Teaching style'* indicates that both EMI and CMI schools score relatively high on Items 1, 2 and 4, but much lower on Items 5 and 6. This means that the science teachers observed, irrespective of whether they use English or Chinese for instruction, put great emphasis on explaining science concepts or delivering instruction to students (Item 1) and establishing a good learning atmosphere in the class (Item 2), while the students are attentive and keen in science lessons (Item 4). These features are characteristic of a didactic approach in which the main task of a teacher is to transmit scientific knowledge to students through lecturing, as it is believed by many teachers to be the most effective way of making students to learn (Gallagher, 1993; Lemberger *et al.*, 1999; McRobbie and Tobin, 1995). This view is consistent with the students' general perception that they seldom ask questions on the lesson content, and very few interactive activities that promote student participation are taken place in science lessons. The consequence of this mode of learning is reflected in students' performance in public examinations. It is reported that Certificate level science students (S5 or 16 year olds) are good at recalling factual information, but are weak in applying their knowledge to novel situations or to solve realistic problems (HKEA, 1999).

Despite the prevalence of a teacher-centred approach in science lessons in general, analysis of the scores on individual items and the videotaped lessons does reveal some substantial differences in the teaching styles of the EMI and CMI science teachers. To illustrate how the teaching styles may be affected by the medium of instruction, reference will be made to specific episodes of the observed lessons in the following discussion.

According to the observations based on Item 1, the EMI teachers tended to spend more lesson time on lecturing or instruction than the CMI teachers. Whenever the lesson involved some worksheet exercises or practical activities, the EMI teachers were generally more concerned with passing on the correct answers or results to their students than the CMI teachers (Item 3).

For most of the lessons observed (i.e. Lessons E-3, E-5, C-1, C-2, C-4 and C-5), the teacher was attentive to the learning climate of the class and alert in motivating the students (Item 2). In cases where this was less marked (e.g. Lesson E-1), the teacher remained at the bench most of the time, speaking to the screen, which showed the notes of the lesson, instead of facing the class. A possible reason for this is that the teacher was not fluent in spoken English and so did not have much confidence in using English for communication. The lack of eye contact with the class also indicates that the teacher was not alert to students' non-verbal responses such as signs of inattention or frustration. The teacher's inadequate expressive skills can be illustrated by the common occurrence of incoherent explanation and ambiguous questions in Lesson E-1 as depicted below, with the author's comments added in italics:

- T (teacher) talking to the class at the start of the lesson: How many kinds of nutrients? [No response from the class.] *(The class does not appear to understand that the teacher is referring to the types of food substances present in the daily diet.)*

- T: Look at this diagram – a food pyramid, how much of each should be taken? You should pay attention to the amount needed. You should eat most cereals, relatively large amount. Then food you should eat medium amount. *(These statements are fragmentary and lack logical coherence. They are not comprehensive to the class.)*

- [T refers to a chart shown on the screen, pointing at the data for the child and the baby.]

  T: Why is there such a great difference between these two groups of people? [After repeating the question for a number of times, T names a student.] *(The question is not clearly phrased. It refers to the difference in energy requirement between the child and the baby. The teacher does not try to rephrase the question or provide any prompts to improve students' response.)*

  Student: ..... *(muttering)*

- T: Yes, size. Child has larger size than baby. *(This statement does not explain* *why a child requires more energy than a baby.)*

Why a 6-year boy requires more energy than a girl? How can you understand about this? How do you find out? Give me a wild guess. [T waits and then names a student, but no response.] *(The teacher does not use prompts to guide his students to answer.)*

Although the other EMI teachers observed were more fluent in the use of English for instruction, they shared some common features with the teacher of Lesson E-1. They tended to use short, disconnected statements which often potentially misrepresented abstract or complex ideas to the students. As discussed in the part on *'Communication skills'*, this characteristic of sentence pattern used by the EMI teachers is likely to be an attempt to reduce the linguistic demand of the lesson so as to cater for the limited English proficiency of the students.

The EMI teachers were more concerned with ensuring that their students could get the right answers or results for their worksheets or experiments than the CMI teachers (Item 3). After the class had completed practicals or worksheets, the EMI teachers usually checked answers with the class without spending much time discussing with their students or assessing their students' understanding. Some EMI teachers did attempt to promote more interaction among the class, but their effort was often met with little success as the students were usually very reluctant to voice their views. Again this was possibly due to their incapability or lack of confidence to express their ideas in English.

The CMI teachers, on the other hand, showed less tendency to check correct answers with their students. They had a greater degree of interaction with the class when going through the answers on the worksheet or the results of an experiment. In comparison with the EMI teachers, the CMI teachers tried more often to elicit students' responses by asking individual students or groups instead of giving out the answers directly.

The extent of student participation, as measured by the frequency of student questions (Item 5) and the use of interactive activities (Item 6), reveals that the science lessons observed are rather teacher-centred for both EMI and CMI schools and are dominated by teacher talking. This can be related to the belief commonly held by teachers that learning involves the transmission of knowledge from the teacher to the students, instead of viewing learning as a process of active construction of knowledge by the students. However, the students of the EMI schools were particularly reticent in the observed science lessons, as they rarely asked questions related to the lesson content, or responded actively to teachers' questions. This is the case for all the EMI lessons observed, irrespective of the style or experience of the teachers. In most lessons, the main student activities were copying notes from the chalkboard, dictating key points from the teacher, or completing worksheets or exercises assigned by the teacher. Even for teacher questions, the EMI students responded much more passively than their CMI peers, a point that will be further elaborated in the part dealing with '*Questioning skills*'. For the CMI lessons observed, student questions were not common, but did happen occasionally when the teaching style was appropriate and when the topic was related to the students' daily experiences, as illustrated by the examples below:

Lesson C-2: The teacher started the lesson with the fact that detergents might be alkaline or acidic. This immediately stimulated some students to ask why some detergents were harmful to the skin, and whether this was related to the pH of the skin.

Lesson C-5: The students raised some questions after the teacher had explained the importance of focusing with the human eye, such as "Can we focus by changing the distance between the lens and the retina?" and "Why some people cannot see distant objects clearly?" Asking these questions indicates that the students were attentive and keen to learn, and they were motivated to relate the subject knowledge with their everyday experience. A reason for the lack of such questions from the EMI students is that they were limited by their proficiency in English; they took more time to internalize teacher's explanation and they were less confident in asking questions in English.

As pointed out at the beginning of this section, lecturing is the most common mode of instruction in the science lessons observed. This explains why interactive activities such as group discussion, debate and role play, which assign the responsibility of learning to students, seldom took place in science lessons. The medium of instruction, however, seems to have some impact on the use of interactive activities in science lessons. These activities were absent in the five EMI lessons observed but were found to occur in two of the CMI lessons, as illustrated by the examples quoted below:

Lesson C-2: Before performing an experiment described in the workbook, the students were given a few minutes to discuss how to design the experiment, including how to set up the control. After completing the group experiment, the students worked in groups to discuss their results and draw conclusions.

Lesson C-5: After watching the demonstration on the causes of short-sight and long-sight using the eye-ball model, the students worked in groups to draw the ray diagrams to illustrate the effects of the various eye defects and suggest ways of correction. Each group had to report their ideas to the class at the end of the lesson.

Although group work was done in both EMI and CMI science lessons, a basic difference is that the EMI students tended to complete their worksheets individually with little interaction among members of the same group. On the completion of the group work, the teacher usually checked the answers with the whole class to ensure that all students got the right answers for revision purposes. In the CMI classrooms, the teacher usually provided more opportunity for students to plan their experimental design among themselves, or to discuss their results and ideas in small groups. Since the EMI students were allowed to communicate with each other in their mother tongue during group work, it is difficult to understand why the EMI students were more incline to work individually instead of in groups than the CMI students. A possible reason is that the EMI students needed more time to complete the worksheet in English, and it would be less time-consuming if the teacher checked the answers on the worksheet with the whole class instead of allowing the students to discuss among themselves and report their results in English. Furthermore, as many of the EMI students had difficulties in expressing their ideas fluently and effectively in English, they were reluctant to respond during class. A quiet class of attentive students showing little interaction with the teacher is a common scene observed in the science lessons of the EMI schools.

2. Questioning skills

Questioning skills serve a number of important roles in the learning of science. Science teachers ask questions in order to check whether their students possess certain prerequisite knowledge for a new topic, to assess their understanding of the lesson content, to test their ability to apply scientific knowledge in different contexts, and to help them construct new concepts from existing knowledge (Barden, 1995; Bloom *et al.*, 1956; Yip, 1999). Questions are also used by teachers to gain class control, to promote student motivation, and to enhance the participation of passive learners. As the effective use of various questioning skills has an important bearing on the learning of science, a comparison of the practice of these skills in EMI and CMI science lessons will contribute to understanding the impact of medium of instruction on science learning.

Asking recall-type questions occurs occasionally in both EMI and CMI classes (Item 7). These questions are usually of low cognitive demand, serving to refresh existing knowledge or to maintain students' attention. Besides asking recall-type questions, the

EMI teachers' question repertoire was limited. While the EMI teachers spent a lot of time "lecturing", they seldom asked questions to assess their students' understanding of the lesson content (Item 8), or used high-order questions to evaluate whether their students could internalise the knowledge learned in class for problem-solving or decision making (Item 9). The following episode taken from one of the EMI lessons can illustrate this:

Episode 1 taken from Lesson E-1 (Energy requirement):

T uses an overhead projector to show a chart which indicates the energy requirement of different people, followed by a brief description. T points to the figures for the child and the baby in the chart.

T: Why is there such a great difference between these two groups of people *(in energy requirement)*? [No response from the class. T asks the same question again.] Give me a wild guess. [Still no response from the class. T names a student to answer.]

S: ..... *(muttering)*

T: Yes, size. Child has larger size than baby. *(This is not a scientific explanation.)*

Compare the boys and girls. Why a 6-year boy requires more energy than a girl? How can you understand about *(explain)* this? How do you find out? Give me a wild guess. [No response from the class.] Any suggestions? [T names a student to answer, but no response from the student.]

T: O.K. Because boys have a higher metabolism to cope with the kind of activities they engage in because in evolution boys suppose to require to perform labour work. So physiologically they require more energy than girls. What other ways does energy requirement related to? [T names a student.]

S: Age.

T: Yes. Right, age. [T elaborates, facing the screen most of the time when talking to the class.] Besides size, sex and age, what else?

[No response from the class. T waits and names a student.]

S: Occupation.

T: Yes, you can see that farmers need more energy than office clerks. What are the base *(reason)* behind? [No response from the class.] Why?

Key: T stands for "Teacher"; S for "Student"; notes/comments added in by the author are in italics.

The above episode is typical of the types of teacher questions generally asked in the EMI science lessons observed. The interaction between the teacher and the students in the sample of EMI classes was as follows:

- The teacher's questions are of low cognitive demand, requiring only one-word or simple answers from the students. The students usually reacted passively to the teacher's questions (Item 12), or rarely gave long, thoughtful responses that were required by the questions asked (Item 11). Given that these students were more academically oriented than their CMI peers, this observation strongly suggests that the EMI students were constrained by their limited communicative skills in English to give elaborated answers. They might have acquired the concepts, but were unable to verbalise their understanding well.

- When the class responded passively or gave a wrong answer, the teacher did not attempt to rephrase the question or use prompts to guide the students to apply their knowledge (Item 10). The failure to use probes may be attributed to teacher's deficiency in pedagogical knowledge, which is related to the experience and training of individual teachers. This is, however, not a likely reason in this study because all the EMI teachers observed have a very low score in this item, in contrast with the satisfactory performance of the CMI teachers. A possible explanation of the poor performance of the EMI teachers is that teaching science in a language in which students have limited proficiency differs significantly from teaching the same content in students' first language. Besides the use of simple questions and short sentences for classroom communication, the EMI teachers need a repertoire of strategies to guide their students to understand the questions asked and verbalise their answers in English. Some of these teachers might have also been constrained by their own proficiency in English, which prevents them from using prompts and cues in an effective way.

- The teachers tended to accept unclear or even inaccurate answers from students. Again, this may have been related to the inadequate English proficiency of the students, who experienced difficulties in expressing abstract and complex ideas accurately. In order to save lesson time, it would be more efficient for the teachers to give the correct answers directly, instead of spending time to guide students to express their ideas in English.

The CMI teachers, on the other hand, asked more questions that assess student understanding or higher cognitive skills (Items 8 and 9) in the science lessons. The following episodes from Lessons C-2 and C-5 illustrate the type of interaction related to the use of questioning skills in the CMI classroom.

Episode 2 taken from Lesson C-2 (pH indicators):

T introduces different types of household detergents, shampoos and bath cream.

T: Have you noted about the pH value of Johnson and Johnson's and other shampoos and bath cream?

S1: 5. S2: 5.5

T: Yes, a pH value of 5.5. What is meant by pH 5.5? [T explains briefly the relationship between pH and acids and alkalis to refresh students' previous knowledge.] So what is meant by a pH of 5.5?

S: Acidic.

T: Yes, slightly acidic. Why are some shampoos and bath cream acidic? Why not use ordinary detergents for cleaning our body?

S: They attack the skin.

T: Yes, good. Our skin is covered by a protective layer, which is slightly acidic. If we use an alkaline detergent, it will remove this layer and damage the skin. You should warn your mom to be careful.

S: Can you explain again why ordinary detergents are not good for our skin? [T explains again.] Is your skin smooth? [T smiles but disregard the question.]

T: Both strong acids and alkalis are corrosive. If we have to handle these chemicals, what safety precaution should be observed?

S3: Wear gloves. S4: Goggles as well.

T: What will you do if some strong acid is spilt on your hand?

S: Wash with water.

T: [T shows a bottle of pH indicator.] What is a pH indicator? Any example?

S: Hydrogencarbonate indicator.

T: Do you still remember the colour changes of the hydrogencarbonate indicator?

[T guides students to recall the colour changes.] So a pH indicator can indicate whether a substance is acidic or alkaline by its colour. In today's experiment, you will study other pH indicators such as tea. Please refer to Activity 10C on p. 59 of your workbook.

[T gives brief instruction of the experiment. Students get apparatus and materials and work in groups to compare the pH of various substances using tea as the indicator.]

Episode 3 taken from Lesson C-5 (Focusing with the eye):

T shows a blurred photo and a clear photo of the same landscape on the screen.

T: What is the difference between the two photos? What is the cause of the difference?

[Students raise up their hands immediately. They are keen to answer the questions.]

S: The first one is not in focus. The position of the lens is incorrect.

T: What is meant by 'in focus'?

S: Forms a sharp image. But how can we form a sharp image with our eyes?

[T introduces focal length. She asks the students, working in groups, to find the focal length of two lenses of different thickness.]

T: How is the focal length of a lens related to its thickness?

[Students work in groups to find out the focal length of different lenses. After 5 minutes, they report their results. The teacher guides the class to draw a conclusion from their results.]

T: Where is the image formed in the eyeball?

S: On the retina.

T: Right. [The teacher projects a ray diagram of the eye on the screen.] The light rays from the object are bent when passing through the lens and focused onto the retina to form a sharp image. Try to find out how the shape of the lens would change when the eye is focusing at a close object and a distant object.

[Students discuss in groups to decide on the method to be used for their investigation. They ask their teacher questions related to the design of their method.]

The episodes taken from the CMI science lessons indicate that the CMI students, in comparison with the EMI students, are more active in responding to teacher questions, and are more motivated to answer or raise questions on the lesson content. Although most of the answers provided by the students were based on recall, occasionally they were able to put forward insightful ideas that indicate genuine understanding and creative thinking, e.g. a student suggesting that an alkaline detergent might be corrosive to the skin; explaining that focusing of an image can be achieved by varying the distance of the lens; proposing methods to show how objects at different distances can be focused by the eye by changing the shape of the lens. The students in Lesson C-2 were actively involved in the learning process through their ready response to teacher questions using preexisting and newly learned knowledge. By discussing among themselves and with guidance from the teacher, the students in Lesson C-5 demonstrated the ability to design a method to solve the problem posed and then construct a theory to explain the accommodation of the eye by varying the thickness of the lens. Such a high level of interaction between the teacher and students was not observed in the EMI lessons.

The development of a more proactive classroom atmosphere in the CMI lessons can also be attributed to the more effective use of probing skills by the teachers. For example, the teacher in lesson C-2 used prompts to help her students to relate their everyday life experience to the pH context, and alerted them to the relationship between their previous knowledge on hydrogencarbonate indicator and the concept of acid and alkali. This skill is also employed by the teacher in Lesson C-5 in guiding her students to verbalise their own understanding of the meaning of focusing and relate this concept to the functioning of the eye.

While most teacher questions, irrespective of the medium of instruction, were of low cognitive demand, the questions asked by the CMI teachers were more specific and clearly expressed than those of the EMI teachers. As a result, the CMI students could understand better the expectations of their teachers and, because they could express fluently in their mother tongue, were more motivated to respond in the class. Furthermore, the questions of the CMI teachers were usually more coherently organised so that the students could be led step by step, through the use of short questions, to build up new concepts from their existing knowledge.

3. Communication skills

The teachers in all the observed lessons generally demonstrated adequate communication skills (Item 13). Compared with the CMI teachers, the EMI teachers tended to use relatively short, simple sentences for communication in class. This is understandable in view of the limited English proficiency of the EMI students, and sometimes of the teachers themselves. The use of simple English is satisfactory when dealing with factual information and simple ideas, but the type of English needed becomes more complex when more abstract or complex concepts are involved. This problem is vividly illustrated by Episode 1 taken from Lesson E-1. Through the use of inaccurate, fragmentary phrases and sentences, the teacher could not communicate scientific ideas effectively in the lesson. The students were unable to form a coherent picture of the factors affecting energy requirement, and to understand the effects of these factors. This inevitably leads to a lower quality of explanation by the EMI teachers (Item 14). The possible effects of inadequate communication skills on science learning can be further illustrated by Episode 4 taken from Lesson E-3.

Episode 4 taken from Lesson E-3 (Heat transfer):

T: What is heat? [No response from the class.] Heat is energy.

T: [T shows two glasses of water.] How to tell which glass of water has more heat?

S1: Use a thermometer.

T: To measure what?

S2: Temperature. *(Note that the teacher has not guided the students to develop a correct concept about the heat content in each glass of water, which is dependent on the temperature of the water as well as the mass of water present.)*

T: If a glass of water at 80°C is left at room temperature, what will happen?

P: The temperature will drop.

T: Why does the temperature drop? How's the amount of heat? What's the change in the amount of heat?

S3: Less heat.

T: The temperature drops because there is less heat. Where does the heat go? Go to ...?

S: Air.

T: Heat is lost to the surrounding. So what is the condition for heat flow from one place to another? What can we say...?

S4: ..... *(muttering)*

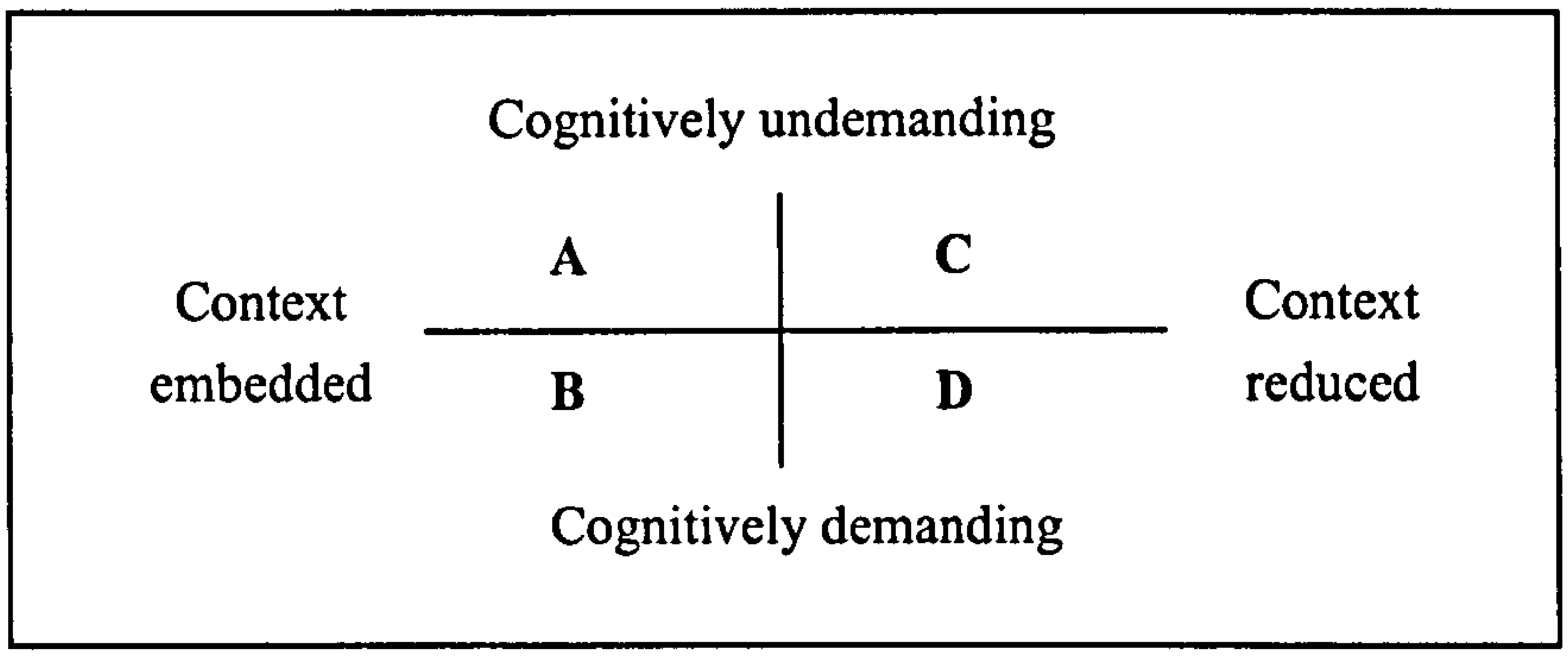
T: The first deduction: a difference in temperature in order to have heat flow. From which place ....? [No response from the class.] In order to have heat flow, must be difference in temperature.

In Episode 4, the teacher attempted to prompt his students to construct the concept of heat transfer through questioning. However, the students were unable to distinguish between temperature and heat content, since they implied from the close relationship between temperature and heat content that they were the same thing. The use of short, disconnected questions did not support the students to weave out a clear picture of the abstract relationship involved.

Similarly, by posing a series of questions on the process of heat loss from a glass of hot water, the teacher of Lesson E-3 attempted to establish that heat always flows along a temperature gradient, i.e. heat flows from a region of higher temperature to a region of lower temperature. The responses from the students, as depicted in Episode 4, show that the students were unable to follow the teacher's line of thought and develop an understanding of the principle of heat transfer. In fact, the deduction made by the teacher could not be arrived at from the example given, and the deduction that a temperature gradient is a necessary condition for heat flow is scientifically inaccurate. Evaporation, another way to transfer heat to be learned in this topic, is a process that can cause heat transfer against a temperature gradient.

The above observations highlight an important issue in immersion education: How to teach cognitively demanding concepts to students with limited English proficiency? The use of English at a simple level to express cognitively demanding concepts is a skill which teachers need to be trained to develop. In relation to this, Cummins (2000: p.66-68) describes a framework to identify the extent to which students are able to cope with the cognitive and linguistic demands made on them in school learning. These demands are conceptualized in terms of two intersecting continua: the range of contextual support for expressing meaning and the range of cognitive demands of academic tasks (Figure 3).

Figure 3 *Range of contextual support and cognitive demands of academic tasks*



In context-embedded communication, as denoted by Quadrants A and B, language use is supported by a wide range of meaningful situational cues such as gestures and intonation. Context-reduced communication, on the other hand, relies primarily on linguistic skills for negotiating meaning. In order to teach cognitively demanding concepts to immersion students with limited English proficiency, teachers need to develop and use a repertoire of context-embedded language skills for conveying meaning. As students progress into higher levels and develop greater competence in English, teachers can convey complex and abstract concepts with more context-reduced language, as denoted by Quadrant D. Based on this framework, Cummins (2000) suggests that second language learners will acquire linguistic and academic growth most successfully when they are challenged cognitively through the use of language that is progressively less context-embedded, i.e. moving from Quadrant A to B, and from Quadrant B to D. This progression corresponds closely to the stages that Gibbons identified in her research on science learning of second language learners (Gibbons, 1998). In Gibbon's study, students initially learned through small-group activities which used context-embedded communication. This was followed by a teacher-guided reporting session, where the teacher interacted with individuals from each group through the use of more decontextualised language, and the students shifted towards less context-embedded ways of expression. The final stage of journal writing, which corresponds to Quadrant D of the framework, provides some evidence of second language growth in that students included in their journals wordings that the teacher used during the guided reporting session.

Based on Cummins' framework, it is therefore possible to design strategies that can be used to teach cognitively demanding concepts to English-limited learners, and facilitate their progression in linguistic and academic growth. However, such skills are not detected in the EMI teachers observed in the present study.

The CMI teachers were on the whole proficient with using Chinese for classroom instruction (Item 13). Although the science lessons for S2 and S3 students were mainly concerned with simple, low-level scientific knowledge, the quality of explanation provided by the CMI teachers was usually good (Item 14), as illustrated by Episodes 2 and 3. In Episode 2, by refreshing the students' knowledge on the colour changes of the hydrogencarbonate indicator in different pH, the teacher helped her students to consolidate the concept of pH indicator. Genuine understanding was demonstrated by the students as they could apply their existing knowledge to design an investigation using tea as pH indicator. Episode 3 shows how the teacher guided her students to verbalise their prior understanding of the meaning of focusing and to explore the relationship between the focal length and the thickness of a lens. With the aid of a diagram, the teacher provided a clear and brief explanation of how focusing was achieved in the eye. Equipped with this background knowledge and through discussion among themselves and with the teacher, the students were able to design methods to investigate how the eye can focus on objects of different distances.

For the ten science lessons observed, the students seemed attentive and keen to learn. No disciplinary problems were encountered. Mobility in the classroom was appropriate (Item 15), although the EMI teachers showed slightly less mobility than the CMI teachers. Most of the lessons were conducted in the laboratory and so teachers usually had to use a microphone which effectively restricted their mobility to the vicinity of the teacher's bench. Thus the small difference in mobility between the EMI and CMI teachers should not be attributed to the medium of instruction, but rather to the physical environment of the venue for the science lessons. The teachers were on the whole attentive to the class (Item 16). The teacher of Lesson E-1 is scored lower due to tendency to face the screen instead of the class when referring to the information displayed.

The medium of instruction does not seem to affect the commitment of the teachers as all teachers were energetic and enthusiastic (Item 17). The CMI students appeared to demonstrate greater interaction among themselves during discussion or practical work than the EMI students (Item 18). This difference can be attributed to a number of reasons, such as the nature of the topic under study and the teaching style of the teacher. In the discussion under 'Teaching style', it has been noted that during the lesson the EMI students were more concerned with completing their own worksheet than participating in group discussion than the CMI students. A reason suggested to account for this behaviour is that the EMI teachers, mindful of limited levels of English proficiency of their students, were more prone to check the worksheet answers or experimental results with the whole class instead of allowing the students to discuss among themselves and report their results in English. This interpretation is consistent with the observation based on Item 3.

CONCLUSIONS

Since the curriculum reforms in the 1960s, a major aim of science curriculum is to foster conceptual understanding in students rather than the mere memorization of scientific knowledge. However, many science teachers today still believe that their primary role is to identify the major concepts in science and present them in an intelligible way to students. According to this belief, conceptual understanding and meaningful learning will occur naturally after students have acquired a critical mass of facts, and therefore the most direct and effective way of science learning is through didactic teaching (Lemberger *et al.*, 1999; Yerrick *et al.*, 1997). This teacher-centred mode of instruction is also found to dominate the science classrooms of the present study, irrespective of the medium of instruction used.

The findings based on the survey of students' perception, however, reveal that there are substantial differences between the teaching styles of the EMI and CMI teachers. Compared with the CMI teachers, the EMI teachers were more focused on exposition of subject content and transmission of established scientific knowledge. Concomitantly, the

EMI students rarely participated in interactive activities such as group discussion, and their practical work was basically made up of recipe-type experiments and teachers' demonstrations.

These findings from students' perceptions are consistent with the assessment based on direct observation of science lessons. Although only a small number of lessons have been observed and the sampled teachers are not representative of the larger population, there are some distinct differences between the teaching styles of the EMI and CMI science teachers. In all the science lessons observed, the students were generally attentive and listened to their teacher's explanation for most of the lesson time. However, relative to the CMI lessons, the EMI lessons were more dominated by teacher talking, and the teachers were more concerned with checking answers on worksheets or experimental results with the students. Moreover, there was little interaction between the teacher and the students in the English-medium lessons. The EMI students were on the whole much more passive than the CMI students in responding to teachers' questions or raising questions on the lesson content.

The more passive role of the EMI students in the classroom or laboratory can be partially attributed to the problems of learning science in a second language. As the EMI students are limited by their low levels of English proficiency, there is a significant gap between how they conceptualise in English and how they conceptualise in their own native language, and between what they can understand in English and what they can articulate in English (Teemant *et al.*, 1995). To bridge such gaps, it may be necessary to make special provisions for these students in learning science. On one hand, teachers should be trained to develop the skills for using context-embedded language to express cognitively demanding concepts. On the other hand, more time should be allowed for the transition from CMI to EMI, so that the students can build up their proficiency in English before total immersion takes place. These students may also benefit from appropriate use of their native language to communicate abstract ideas, and to raise questions and answer them. Their teachers may occasionally supplement their explanation or instruction with Chinese, at least in the early years of the immersion programme (Martin, 1999; Rollnick, 1998). Such practices, however, are prohibited by the current language policy.

The questioning skills in science lessons are strongly affected by the medium of instruction. In the EMI science lessons, the teachers mainly asked low-level questions that require simple, recall-type answers. They rarely asked high-order questions that assess students' understanding of lesson content or conceptual change. The CMI teachers, on the other hand, asked more high-order questions, and their students were more active in responding to teachers' questions. The difference in the difficulty level of teacher questions between the EMI and CMI science lessons can be related to the students' proficiency in the language of instruction. The domination of low-level questions and the lack of high-order questions in the EMI science lessons is very likely a compromise, since most students can only express simple ideas and factual information in English. Despite their overall higher academic abilities than their CMI peers, the EMI students were passive in answering even recall-type questions, and they rarely gave elaborate answers. This type of interaction leads the teacher to dominate the talk in class, asking only recall-type questions, and most often answer their own questions. In contrast, the CMI classrooms were more interactive, with the students playing a more active role in answering and asking questions. The CMI teachers also demonstrated better skills in the use of probes to improve students' responses and guide them to develop more in-depth answers. In an EMI classroom, when the students showed no response to a teacher question, or answered wrongly, the teacher seldom attempted to elicit better responses by rephrasing the question, or cue the class to apply their knowledge in constructing a solution, but often provided the correct answer directly.

Taking account of the limited English proficiency of their students, the EMI teachers tended to use more simple sentences or phrases for instruction than the CMI teachers. This was adequate for explaining simple concepts or delivering factual information. For more abstract or complex concepts, the quality of learning was affected. The use of disconnected, short statements did not lead to coherent explanations and thus appeared to limit the development of meaningful learning as intended for the students. The EMI teachers involved in this study basically possessed adequate subject knowledge and were proficient in English. However, they have to be equipped with skills and strategies to ensure that their students develop subject knowledge and language skills, as teaching science in a language in which students have limited proficiency is much more demanding than teaching the same content in students' first language. This difference implies a need for the provision of training programmes for EMI science teachers through which the teachers can develop effective instructional strategies that promote meaningful learning in students despite their limited language proficiency (Edmunds, 2000; Met, 1998).

To sum up, the differences between the EMI and CMI schools in the nature and quality of instructional activities in science lessons suggest that the EMI students have more limited learning experience than their CMI peers. This finding does not support the assumption made by the policy makers of the new language policy that this group of elite students is capable of learning effectively in English. Despite the initial high academic ability of the EMI students, there is still a large gap between their proficiency in the mother tongue and in English. The limited English proficiency of the students makes it difficult for the teachers to communicate to them the subject content of science in English, and for them to understand and conceptualise the abstract and complex relationships of science concepts in English. The realization of this constraint points to a need to reconsider the rationale of the new language policy which stipulates that the EMI students must learn science and other content subjects through a complete immersion in English, without using L1 in a supportive role. With reference to Cummins' framework of linguistic and cognitive demands of academic tasks, there is also a need for teacher educators to provide programmes that help science teachers develop the skills for teaching cognitively demanding concepts in simple English, and for guiding their students to move towards less context-embedded communication as they show advancement in linguistic and cognitive abilities.

CHAPTER 7

CHANGES IN THE EFFECTS OF MEDIUM OF INSTRUCTION ON SCIENCE LEARNING OVER TIME

This chapter reports the findings on whether the effects of medium of instruction on science learning may change with the time of immersion in the first three years of secondary schooling. As the EMI students experience a sudden change in the medium of instruction from Chinese to English in S1, it is expected that the negative effects of instruction in English may be substantial in the first secondary year, but that such effects may become smaller over time as the EMI students develop greater proficiency in English language skills and are more used to instruction in English. This view is in line with the findings from studies on the Canadian late immersion programmes (e.g. Swain, 1978 quoted in Chapter 2, p.43). On the other hand, as the EMI students progress to higher levels, the science curriculum will include more abstract and complex concepts which make greater demand on language skills. So there is a possibility that the negative effects of English instruction may be exacerbated in the higher secondary levels despite a longer time of immersion.

In this study, the relationship between the effects of MOI on science learning and the time of immersion is studied by comparing the performance of students in different sampling strata on the Science Achievement Tests from S1 to S3, with a focus on the difference between the EMI and CHIG students.

CHANGES IN THE EFFECTS OF SAMPLING STRATA ON SCIENCE ACHIEVEMENT WITH TIME

Using hierarchical linear modeling technique, it is possible to differentiate the school contextual effects on science achievement by replacing the school mean AAI with three dummy variables. The dummy variables are the CHIG, CMID and CLOW strata, using the EMI stratum as the reference point. When these dummy variables are injected into the baseline model to replace the school contextual measure, a new set of hierarchical linear model is constructed. Using this model, it is possible to compare the science achievement of the EMI students with that of the students of the three CMI school strata, after controlling the prior academic ability, socio-economic status and gender of students (Chapter 4, p.101). The values obtained will indicate the magnitude of the effects of the medium of instruction on science learning. The relative performance of the four school strata on the S1-S3 Science Achievement Tests as computed by this technique is presented in Appendices 7-9 and summarised in Table 27 below.

For the three years of study on the 1999 student cohort, the coefficients of the three CMI strata on science achievement, with reference to that of the EMI stratum, are all positive in value and statistically significant. The data indicate that the three strata of CMI schools substantially out-perform the EMI stratum in the S1-S3 Science Achievement Tests.

Table 27 *Summary of effects of sampling school strata on science achievement scores in S1-S3*

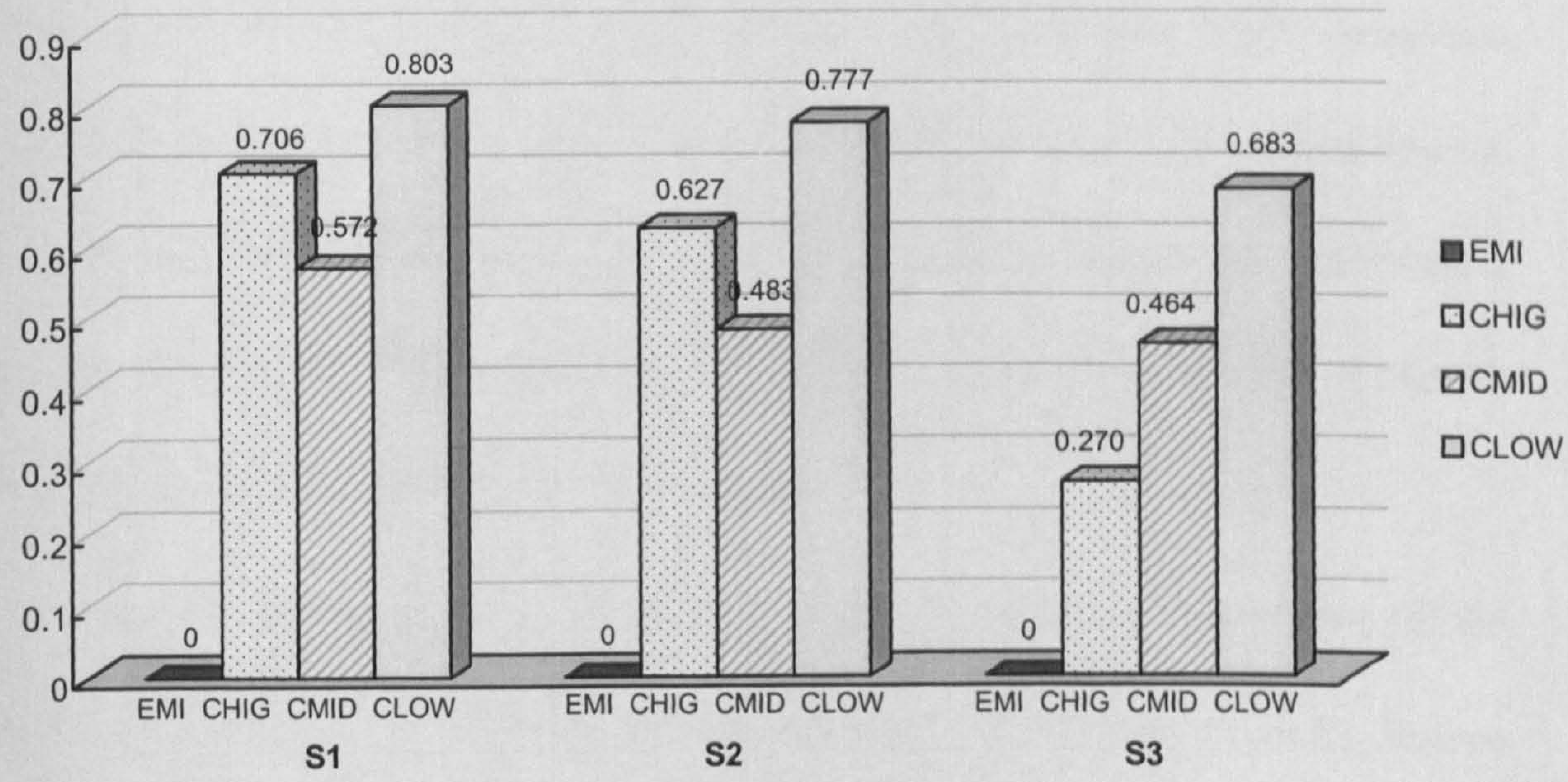
	S1		S2		S3	
Fixed Effects	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
Pupil Level (L1)						
Intercept	-0.597 *	0.107	-0.483*	0.113	-0.451*	0.121
Individual AAI	0.508 *	0.021	0.384*	0.017	0.290*	0.018
Female	0.070 *	0.016	-0.080*	0.016	0.124*	0.021
Individual SES	0.008	0.006	0.003	0.007	-0.013	0.007
School Level (L2)						
Mean AAI	0.235	0.097	0.196	0.106	0.314*	0.095
Mean SES	-0.072	0.075	0.047	0.074	0.037	0.069
Sampling strata						
CHIG Effect	0.706 *	0.079	0.627*	0.088	0.270*	0.114
CMID Effect	0.572 *	0.129	0.483*	0.141	0.464*	0.129
CLOW Effect	0.803 *	0.234	0.777*	0.235	0.683*	0.247
Random Effects						
within-school variance	0.586		0.638		0.642	
% of within-school variance explained	26.933 %		5.449%		3.618%	
between-school variance	0.054*		0.080*		0.141*	
% of between-school variance explained	90.217%		62.693%		45.604%	

* Significant at the 0.05 level

More specifically, the CHIG, CMID and CLOW students out-perform the EMI students by 0.706, 0.572 and 0.803 of a standard deviation respectively in the S1 Science Achievement Test, after controlling individual and school mean AAI, socio-economic status and gender of the students. This indicates that instruction in English has a substantial negative effect on science learning for S1 students compared with instruction in Chinese after one year of secondary schooling. A similar but slightly smaller effect is also detected in the EMI students near the end of S2, i.e. their mean science score is

0.627, 0.483 and 0.777 standard deviation below that of the CHIG, CMID and CLOW students respectively. While the CMI students still out-perform the EMI students near the end of S3, the difference between them continues to drop, particularly between the CHIG and EMI students. Such a trend of decreasing negative effect of English-medium instruction on science learning can be better visualised by presenting the data in a bar chart showing the relative change in science achievement of different school strata with time from S1 to S3 (Figure 4).

Figure 4 *Coefficients of sampling strata on science achievement in S1-S3*



The difference in science achievement between the EMI stratum and each of the three CMI strata is very large near the end of S1, but the difference decreases steadily in S2 and S3 (Figure 4). The narrowing effect is particularly spectacular between the EMI and CHIG students. For the 1999 student cohort in S1 and S2, the coefficients of science achievement of the EMI students is 0.706 and 0.627 standard deviation below that of the CHIG students, whereas in S3 the difference has been reduced to 0.270 standard deviation. This observation shows that the negative effect of English instruction on science learning, as compared to Chinese instruction, has become much smaller after three years of immersion in English.

ANALYSIS OF PERFORMANCE ON INDIVIDUAL ITEMS OF SCIENCE ACHIEVEMENT TESTS

Another way to study the effect of time of immersion on the science achievement of the sampling strata is to compare the performance of the EMI and CHIG schools on individual items of the science achievement tests, which has been reviewed in Chapter 4. Although the three achievement tests for S1 to S3 are based on different curriculum contents and have different cognitive demands, analysis of the differential performance of the two school strata may reveal some of the problems associated with learning science in a second language, and how the negative effect of using EMI on science learning may change with the time of immersion.

Based on the data reported in Chapter 4, Table 29 compares the performance of the EMI and CHIG students on individual multiple-choice items of the S1 to S3 Science Achievement Tests.

Table 29 Comparison of performance of the EMI and CHIG students in multiple-choice items of the Science Achievement Tests

Science Achievement Test	*Performance of EMI and CHIG strata on individual items*		
	EMI > CHIG[1]	EMI = CHIG[2]	EMI < CHIG[3]
S1	Items 6, 9 [*9.52%*]	Items 1, 5, 8, 11, 15, 17, 18, 19, 20, 21, 22 [*52.38%*]	Items 2, 3, 4, 7, 10, 13, 14, 16 [*38.10%*]
S2	Items 1, 7, 8, 21, 22 [*21.74%*]	Items 2, 5, 6, 13, 15, 16, 17, 23, 24 [*39.13%*]	Items 3, 4, 9, 10, 12, 14, 18, 20, 25 [*39.13%*]
S3	Items 4, 8, 11, 13, 15, 16, 17, 18, 24, 30 [*37.04%*]	Items 2, 3, 5, 7, 9, 10, 14, 19, 21, 22, 26, 28, 19 [*48.15%*]	Items 1, 12, 23, 27 [*14.81%*]

[1] Items in which the EMI students out-perform the CHIG students

[2] Items in which the EMI and CHIG students show comparable performance

[3] Items in which the CHIG students out-perform the EMI students

The first data column in Table 29 lists out the items in which the EMI students score better than the CHIG students. Despite their higher initial ability at the start of secondary schooling, the EMI students out-perform the CHIG students in only two items in S1 (9.52% of total number of items), but the percentage of such items increases through S2 (21.74%) to S3 (37.04%). This trend is consistent with the finding from the multi-level analysis which compares the coefficients of sampling school strata on science achievement in S1 to S3 (Figure 4). The trend of change suggests that the negative effect of learning science through English, as compared to that through Chinese, decreases in magnitude as the EMI students proceed to higher secondary levels. As discussed in Chapter 4, most of the S1 and S2 test items that are better scored by the EMI students are of relatively low cognitive demand. They mainly assess the ability to recall or simple application of scientific knowledge. This is understandable because such items make less demand on language abilities than the higher order questions and so the EMI students would be less handicapped when answering them.

For the S3 test, the EMI students out-perform the CHIG students in a much greater number of items. Moreover, some of these items assess higher cognitive abilities, such as understanding of abstract concepts (Items 8, 18) and application of scientific knowledge in realistic or novel situations (Items 16, 24). Conversely, there is a substantial drop in the percentage of items in which the CHIG students out-perform the EMI students, from 38.10% in S1 to 14.81% in S3. These results indicate that after three year's of immersion in English, the EMI students of the 99-Cohort have gained much progress in science achievement, relative to their CHIG counterparts, and their progress in achievement is evident in items of both low and high cognitive demands. The observations made in the present study about the effect of time of immersion on science learning of the EMI students are consistent with the conclusion made in other studies that, under supportive conditions, the initial negative effects of learning content subjects in a second language will be reduced or eliminated after one to several years of immersion (Genesee, 1987; Swain, 1978). Marsh *et al.* (2000) also reported in their study on Hong Kong students that the achievement differences in history and science between EMI and CMI students were smaller at S3 than S1, although the differences were not substantial. The finding of Marsh and his co-workers, however, has to be interpreted with caution because their study was conducted before the implementation of the new language policy in 1998.

Many of the EMI students in their study were not selected according to academic ability and were limited in English proficiency. As these students had problems in learning subject matter through English, they were not exposed to genuine English-medium instruction in school, but were instructed through Cantonese or mixed code most of the time. They might not have benefitted greatly from the immersion approach which aims at developing L2 proficiency through the meaningful use of L2 as a medium of instruction for learning content subjects.

CONCLUSIONS

Multi-level analysis of the science achievement scores of the sampling strata indicates that, after controlling prior academic ability and other factors such as gender and socio-economic status of the students, the EMI students show lower performance than the students of the three CMI strata in the first three secondary years. There is, however, a clear trend that the gap between them narrows up as the time of immersion increases, particularly between the EMI and CHIG schools.

The fact that the negative effects of learning science through English decrease with time strongly suggests that these effects are caused by the limited English proficiency of the EMI students. The effects are strongest in S1 because the EMI students experience a drastic change in the medium of instruction from Chinese to English in their first year of secondary schooling. As they become more proficient in English and more familiar with instruction in English in S2 and S3, they will become more capable and confident of using English to acquire subject matter knowledge, leading to a better science achievement over time.

In S1 and S2, the EMI students were found to out-perform the CHIG students in a small percentage of items, which are mainly of low cognitive demand. By the time of S3, they had gained greater success and out-performed the CHIG students in a much higher percentage of items, some of which assess abstract concepts or demand higher cognitive skills. This observation provides support for the conclusion based on multi-level analysis that the negative effects of learning science through English diminish with the time of immersion.

However, even with this improvement, the EMI students still lag behind their CMI peers in science achievement after three years of immersion in English. This is different from the Canadian late immersion programmes, in which the immersion students show little or no negative effect on learning of academic subjects compared with the non-immersion students after one to several years of immersion. The larger lag of the Hong Kong immersion students in science achievement, in comparison with the CMI students, may be due to the great difference in linguistic structure between the Chinese and English languages. Another possible reason is that there is not enough support for the EMI schools to implement the immersion programme in Hong Kong, especially in the field of teacher training. The relatively successful outcomes of the Canadian immersion programmes have been attributed to a variety of factors such as student motivation, teacher preparation, home culture and parental attitude (Carey, 1991: p.953). Based on the present finding, it can be anticipated that the EMI students of Hong Kong, compared with the Canadian French immersion students, may take a longer period to catch up with their CMI counterparts in science learning, by following the present policy for implementing the English immersion programme. To testify this anticipation, there is a need to extend the current longitudinal study to find out what happens to the 1999 student cohort at the end of their secondary schooling. At present, the author is planning the second phase of the study, which aims at tracking the science learning of the 99-Cohort through S4 to S5. By the end of S5, these students will take the Hong Kong School Certificate of Education Examination (HKCEE), which is a high-stake public examination equivalent to the GCSE of the U.K. Comparison of the HKCEE grades in science subjects obtained by the EMI and CMI students of this cohort will reveal the long-term effects of learning science through different media of instruction as stipulated by the language policy of the *Guidance*.

CHAPTER 8

IMPLICATIONS OF FINDINGS AND RECOMMENDATIONS

In Chapter 3 (p.66), the following two research questions are formulated: (1) What are the effects of MOI on the science achievement of secondary students? and (2)What are the effects of MOI on students' self-concepts in science? However, restating these two research questions leads to the reconceptualisation of the whole study as consisting of four main lines of inquiry:

1. the effects of MOI on the science achievement of students
2. the effects of MOI on the science self-concept of students
3. the effects of MOI on instructional activities in science lessons
4. the changes in the effects of MOI on science achievement over time

In this last chapter of the thesis, a summary of the findings in these four areas and their implications will be presented first. This summary provides a holistic picture of the impact of the new language policy as stipulated in the *Guidance* on science learning of junior secondary students, and offers answers to the research questions set out in Chapter 3.

Based on these findings and implications, recommendations are made on how the immersion programme in Hong Kong can be implemented more effectively, with particular reference to the problems identified in this study on the process of science learning of the EMI students.

SUMMARY OF FINDINGS AND IMPLICATIONS

1. Effects of MOI on science achievement

For the 1999 student cohort involved in this study, achievement in science is measured by their performance on the Science Achievement Tests. Analysis of variance reveals that the differences in mean scores in science achievement among the four school strata are all statistically significant through all the three junior secondary years, i.e. S1 to S3 (Table 4, p.96). Among the CMI schools, science achievement is positively related to students' prior ability as measured by mean school AAI. This means that the CHIG schools show the highest science achievement, followed by the CMID schools and then the CLOW schools. Despite the higher mean AAI of the EMI stratum, the EMI students demonstrate lower achievement in science than the CHIG students. Multi-level analysis also shows that all CMI strata substantially out-perform the EMI stratum in science achievement after controlling the AAI, gender and socio-economic status of the students (Table 7, p.102).

Item analysis of performance on the S1 and S2 Science Achievement Tests (p.105-107, 115-118) indicates that initially the EMI students out-perform the CHIG students in only a small number of multiple-choice items, which have relatively low cognitive demand such as direct recall or simple application of science concepts. For multiple-choice items that demand higher order thinking, the mastery of scientific terminology and the application of scientific concepts or models to explain everyday phenomena, the performance of the EMI students is generally similar to or less satisfactory than the CHIG students. The EMI students, however, show much improvement in science achievement in S3 (p.124-127). They out-perform the CHIG students in 10 multiple-choice items out of a total of 27 items, some of which assess understanding of abstract concepts, mastery of scientific terminology and the ability to apply scientific knowledge in everyday life contexts.

For the free-response items, the EMI students tend to perform less satisfactorily than the CHIG students through S1 to S3, particularly in items that demand integration and organization of concepts to explain everyday life phenomena.

These findings show that immersion in English has negative effects on science learning in the first three years of secondary schooling. They imply that the EMI students, who have been selected for their higher academic ability, are disadvantaged in science learning, as compared to their CMI peers who learn science through their mother language. Probably the EMI students have not yet acquired adequate English proficiency for them to study science subject matter effectively in the English medium. To reduce the negative impact of English immersion on the academic development of these students, special provision and support should be provided to the EMI schools, particularly for the junior secondary students who experience a drastic change in the medium of instruction from Chinese to English when they join the school as S1 students.

2. Effects of MOI on the formation of self-concept in science

Based on the questionnaire responses, students' self-concepts in Chinese, English and mathematics are positively related to their prior academic ability. That is, the EMI students hold higher self-concepts in Chinese, English and mathematics than the students of the three CMI school strata (Table 23, p.140). Among the CMI strata, the self-concepts of students in these subjects descend in the order of CHIG, CMID and CLOW schools. The EMI students, however, show a lower self-concept in science than the students of all the three CMI strata, despite the fact that they score consistently higher than the CMID and CLOW students in the science achievement tests. A possible interpretation for the lower self-concept of the EMI students in science than those in other subjects is that learning science through a second language is particularly demanding. Effective science learning involves the mastery of the terminology and language of science and the conceptualisation of abstract ideas, which make a high demand on language skills as well as the ability of abstract and high order thinking. Such demand makes it difficult for students to learn science through a second language.

As academic achievement has a positive effect on the formation of academic self-concept, the lower science self-concept of the EMI students might have been caused by the negative effects of using English as a medium for learning science. This argument is substantiated by the poorer performance of the EMI students on the S1 to S3 Science Achievement Tests than the CHIG students, and the lower test scores of the EMI students compared with the students of all the three CMI strata after controlling prior ability and other contextual factors.

The questionnaire survey also shows that the EMI students perceived greater difficulty in understanding their teachers' explanation than their CMI peers, and they had a stronger impression that science learning requires a lot of memory work (Chapter 5, p.145-147). These responses suggest that the EMI students are constrained in science learning by their limited proficiency in English, and provide an explanation for their weaker performance on items that assess in-depth understanding and higher cognitive abilities. In view of the possible impact of self-concept on subsequent academic development, it may be necessary to consider introducing strategies that foster the development of a more positive science self-concept among the EMI students.

3. Effects of MOI on instructional activities in science lessons

According to the responses to the student questionnaire, the EMI students perceived that they spent more lesson time on listening to teachers' explanation than their CMI peers (Chapter 6, p.153). A possible implication from this perception is that a more didactic, teacher-centred approach is used in the science lessons of EMI schools. This interpretation is supported by students' responses to other items, which indicate that the EMI students engage less in interactive learning activities such as discussion than the CHIG and CMID students.

The EMI students perceived that they had a greater tendency to follow laboratory manuals when doing practical work, but less chance to design investigations by themselves than the CMI students (Chapter 6, p.155). They also indicated that they tended to spend more time watching their teachers doing demonstrations in the laboratory. These differences in perception suggest that the practical activities experienced by the EMI students are more prescriptive and stereotypic in nature.

The more didactic and teacher-centred approach of science learning as perceived by the EMI students, both in the classroom and the laboratory, can be related to the problems of learning science through a second language. Due to their limited English proficiency, the EMI students cannot communicate freely in English and this discourages the use of interactive activities in science lessons. Furthermore, the EMI teachers may prefer to use a didactic approach in which they do most of the talking while their students play the role of listeners.

The problem with this approach is that it minimises the opportunities for EMI students to use and develop English language skills through meaningful discourse in the process of learning science subject matter. Paradoxically, it defeats the purpose of immersion which aims at maximising students' exposure to L2 through its use in the learning of content subjects.

Based on the small number of classroom observations made, science teachers in general, irrespective of the medium of instruction used, adopt a teacher-centred approach in teaching and their students are attentive and keen in science lessons (Chapter 6, p.161). However, the EMI teachers tend to be more didactic and are more concerned with transmitting correct answers directly to their students than the CMI teachers when going through worksheets or experimental results. On the other hand, there is greater student participation during such processes in the CMI classrooms. These observations are consistent with the differential perceptions of the EMI and CMI students of classroom climate in science lessons.

Compared with the CMI students, the EMI students are more quiet and passive in science lessons (Chapter 6, p.165). Their main activities are listening to teachers' explanation or instruction, copying notes or completing worksheets. Even when interactive activities such as group discussion are conducted in class, they are much less active than their CMI peers, although they are often allowed to communicate in Chinese during such activities. It appears that the EMI teachers do not have the pedagogical understanding or skills to take advantage of such opportunities to help their students acquire English language skills through meaningful discourse during lesson time. Although the EMI students are potentially more able in learning, they tend to have developed a more passive learning style than their CMI counterparts.

The EMI students seldom ask questions in class and do not respond actively to teachers' questions (p.165). When demanded to respond, they rarely give elaborate answers that reflect deep understanding. A reason for this is that most teacher questions are low-level and recall in nature. Another likely reason is that these students lack the confidence to express accurately in English, and their teachers do not possess a repertoire of strategies to encourage them to verbalise and develop their ideas in English. The CMI students, on the other hand, show greater motivation to engage in classroom activities and the classroom climate of CMI science lessons is generally more lively and interactive.

Most of the EMI teachers observed can express themselves adequately in English. However, their instruction is mainly composed of short, fragmentary phrases or sentences that may not be able to communicate scientific concepts and relationships coherently and accurately to students (Chapter 6, p.175). This may have been a strategy to cope with the limited English proficiency of the EMI students, but the prevalent use of such kind of English in teaching does not favour science learning or the development of L2 language skills through immersion.

4. Changes in the effects of MOI on science achievement over time

Multi-level analysis of science achievement scores indicates that the EMI schools consistently performed lower than the three CMI strata, after controlling for prior ability, gender and socio-economic status of the students. The difference in performance between the EMI and CMI schools became smaller as the time of immersion increased, particularly between the EMI and CHIG schools. This finding suggests that the negative effects of English immersion lessen as the EMI students gain greater competence and confidence in learning through English.

Analysis of students' performance on the achievement tests also supports this interpretation. In S1 and S2, the EMI students out-performed the CHIG students in only a small number of items, most of which are of low cognitive demand. By the time of S3, the EMI students out-performed the CHIG students in a much greater number of items, some of which assess higher cognitive skills. Comparing the differences of the mean scores between the EMI and CHIG students on the free-response items in S1 (Table 16, p.120), S2 (Table 11, p.112) and S3 (Table 21, p.128) also indicates that the gap in performance narrows down by S3.

These findings imply that, at least in the first three years of secondary schooling, immersion is practised at the cost of lower levels of achievement in science for the EMI students. The observation that it takes time for the EMI students to overcome the negative effects of immersion on science learning points to a need to consider how the lag time can be effectively shortened. An important consideration is to ensure that the demands of the curriculum content match the language proficiency of the students. At present, the immersion students follow the same science curriculum as the non-immersion students starting from the first year of immersion. Curriculum developers could select content that has the potential for successful student learning, particularly in the initial years of immersion when most EMI students are still limited in their English language skills. Another factor to consider is to ensure that the science teachers possess the knowledge and skills for effective instructional practices for teaching science through a second language. The findings based on students' perception of classroom climate and observations of instructional activities in science lessons in this study indicate that the teaching strategies and skills used by the EMI science teachers are inappropriate.

RECOMMENDATIONS FOR THE IMPLEMENTATION OF ENGLISH IMMERSION

The results of the present study show that learning science through English has negative effects on students' achievement and self-concept in science. It thus appears that the EMI students are acquiring English proficiency, a belief that has yet to be substantiated by empirical evidence, at the cost of lower levels of science learning. However, this problem of science learning through a second language should not be taken as an argument against the implementation of English immersion programme in Hong Kong. If the education system of Hong Kong has to produce some students with the high levels of proficiency in Chinese and English that can only be achieved through immersion, the question to ask is what can be done to reduce the negative effects of immersion on the academic achievement and self-concept of the immersion students, and how to help them to make a more smooth and effective transition of the medium of instruction from Chinese to English in the early secondary years. Based on a comparison of performance on the science achievement tests between the EMI and CMI students, their perception of classroom climate and observations of science lessons, the negative effects of immersion can be attributed to two factors, i.e. the limited English proficiency of the EMI students and the teaching approaches prevalent in science lessons. A reconsideration of the impact of these two factors can provide clues on strategies that will enable the EMI students to learn science more effectively.

1. Helping immersion students with limited English proficiency

The Education Commission (1990: p.94) encourages EMI schools to implement intensive bridging courses for their S1 students so as to raise their English standard to a level that will enable them to study the secondary curriculum through English. This scheme is optional and its curriculum is school-based. In schools where it is operated, it is usually conducted in summer before the S1 entrants start their new school year. According to the findings of this study, the bridging programmes alone do not seem to be effective in helping the S1 students in EMI schools to transfer from a Chinese medium to an English one.

The *Guidance* enforces the use of English as the sole medium of instruction in the EMI schools and dismisses the use of switched or mixed code, which has been considered to be a major cause of the low levels of English standard being achieved in the EMI schools (Education Department, 1989). This stipulation, however, has resulted in a classroom climate featured by a teacher-centred, didactic mode of instruction with little student interaction. Such a classroom climate does not provide the opportunities for immersion students to practise the use of the target language through meaningful discourse of science subject matter. This is not in line with the purpose of immersion that L2 learning should be incidental to the learning of science or other content subjects. In order to help students learn science effectively in the early years of immersion, when many of them are still limited in English proficiency, two recommendations are proposed below concerning the implementation of the immersion programme.

Using L1 to support L2 instruction

In the early French immersion classrooms in Canada, students are allowed to speak English to each other and to their teachers (Canadian Education Association, 1992). The teachers do not force their students to use French until they are naturally willing to do so. Early insistence on French may result in the students developing negative attitudes to the French language and to education in general. This Canadian experience is useful for understanding the problems faced by the EMI students in this study who experience a sudden change in the medium of instruction from their native language to a second language that they are much less proficient with. These students are found to be incapable of communicating effectively in English in science lessons. Insistence on using English as the sole language of communication may have been a cause for the relatively low academic achievement and self-concept of the EMI students as compared to their CMI peers. As in the early immersion Canadian programmes, some degree of code switching by the students or the teachers may help to smoothen the transition of MOI in the early secondary years. Full instruction in English can start once the students have acquired competence and confidence in the use of English. Rollnick and Rutherford (1996) also provide some examples from Swazi teachers who use code switching to facilitate the learning of content subjects for immersion students who have limited L2 proficiency. These include repeating the explanation in the Swazi language (L1) of subject matter that has been explained in English, using L1 to help detecting alternative conceptions held by students, and allowing students to clarify concepts in L1.

These considerations lead to the following recommendation for the implementation of the language policy: *A judicious but limited amount of L1 might be allowed in the foundation year to support L2 development.* Such a practice may have positive effects on the academic development and self-concept formation of the EMI students. Johnson (1997), however, cautions against this practice on the ground that code switching is counterproductive because it may become a self-perpetuating substitute for L2 acquisition. Nevertheless, he suggests that it is worthwhile to explore whether L1 can be used in supporting, rather than replacing L2 development, such as for elaborating the meaning of an L2 expression or clarifying instructions for a learning activity. However, further work needs to be carried out to determine the exact nature of this support rather than leaving it under the umbrella of "code switching".

Matching learning objectives with students' language proficiency

According to the immersion policy prescribed in the *Guidance*, both EMI and CMI students follow the same science curriculum. No consideration has been given to whether the language proficiency of the immersion students matches the cognitive demand of the curriculum. A consequence of this is that the EMI teachers find it difficult to teach comprehensively science contents that involve abstract and cognitively demanding concepts to students with limited English proficiency. This problem has been observed in some of the EMI science lessons in this study. Thus exploring how to teach cognitively demanding concepts through a lower level of English is an important component of training programmes for EMI science teachers.

The following recommendation is proposed to resolve the above problem: *Teachers should select subject contents and activities that are progressively within the range of students' linguistic abilities.* Teachers may need to plan the sequence of learning objectives according to the language growth of their students. For instance, it may be more appropriate to teach contents that can be learned through visual and concrete experiences at the beginning of S1, while more abstract and complex concepts are introduced when students have acquired a greater repertoire of linguistic skills.

2. Training science teachers for EMI schools

The present study shows that the science lessons in EMI schools are dominated by didactic teaching with little student interaction. The teachers typically focus on explaining subject content to whole class, and seldom interact with their students through questioning, cueing, or prompting students to respond. The students are generally very passive in the classroom, often just watching or listening to the teacher. Similar observations have been reported in other studies (e.g. Brookhart and Rusnak, 1993; Waxman *et al.*, 1995) on the classroom climate for students learning through a second language. These observations suggest that the science teachers concerned do not possess the skills for making good use of immersion in promoting academic as well as L2 development. In Hong Kong, the science teachers in EMI schools are subject specialists with little training on teaching the subject matter in English. Even if they are proficient in the English language, they may not know how to apply the strategies of effective language instruction in teaching science. Furthermore, teaching science in a language in which students have limited proficiency is quite different from teaching the same content in students' first language. While all effective teachers need a repertoire of instructional approaches, immersion teachers need an expanded repertoire of strategies for addressing the special linguistic needs of students with limited English proficiency. They have to be aware of the level of the students' vocabulary and language abilities, and to teach in English at a level that the students can understand, and at the same time, raising the students' English competence through the learning of science content. Apparently, the science teachers in the EMI schools in Hong Kong lack such knowledge and skills, which can be inculcated through appropriate teacher education programmes. The following are some recommendations for the content of such programmes.

Facilitating student understanding and development of language skills

Snow (1990) provides a list of techniques that tend to be used by experienced and effective immersion teachers. Some of these may be relevant to the teaching of science and to the context of Hong Kong. For example, teachers can enhance student understanding of abstract concepts by using body language such as gestures, facial expressions and acting, extensive use of analogies and visual materials such as models, pictures and audio-visual aids, and using repetition, summaries and paraphrasing. Teachers can also facilitate language development of students by indirect error correction, questioning with prompts and positive reinforcement. These strategies encourage students to produce extended responses, thus providing opportunities for students to practise the use of English through meaningful and authentic discourse. Teachers can make their explanation comprehensible by matching their language to students' language proficiency. They may speak more slowly, use simple language structure and avoid too much vocabulary (Met, 1994).

Knowledge of Cummins' framework on the interaction between the range of contextual support and cognitive demand of academic tasks (Chapter 6, p.174) can help teachers understand the challenges faced by English-limited students when learning abstract or complex concepts in science. With reference to this framework, teachers should be able to develop teaching strategies for conveying cognitively demanding content with language that matches students' language abilities, and instructional sequence of tasks that helps their students acquire linguistic and academic competence progressively through the strategic use of a repertoire of teaching skills.

The effective use of interactive learning activities, such as group discussion, role play, active reading and writing activities, can encourage students to play a more active role in learning. These strategies are effective for promoting conceptual understanding, but they are particularly relevant to second language learners because they provide ample opportunities for these students to use and acquire language skills through authentic and meaningful interactions (Davies and Greene, 1984; Sheffield City Polytechnic, 1992). For example, task-orientated reading activities, also known as directed activities related to text (DARTs), encourage active, reflective reading. They help students understand a passage by focusing on specific targets or goals, and at the same developing students' comprehension skills. These active reading activities include text completion, sequencing, text marking, responding to teacher questions and generating questions by students. Task-orientated writing activities, such as diary writing and writing a journalist report, can improve the English writing skills of students by engaging them in writing tasks that are both context-embedded and cognitively demanding (Cummins, 1981).

The above discussion of teaching and learning skills leads to the following recommendation: *Teacher education programmes at both the in-service and pre-service levels should ensure that immersion teachers are provided with the knowledge and skills for instructional strategies and approaches most suited to EMI.* These interactive learning activities are important for immersion students because they facilitate meaningful learning on one hand, and at the same time provide students with extensive opportunities to develop and use their growing language skills.

Making the language of science comprehensible

Science uses a special language which is considered to be a major barrier to learning in science (Wellington, 2001; Wellington and Osborne, 2001). This language problem is particularly serious for EMI students who has to learn science through a second language. Workshops should be organized for science teachers in EMI schools to make them aware of this problem and equip them with the skills to help students overcome it.

Learning science involves the acquisition of a set of vocabulary that is unique to science but seldom used in everyday life. These science terms may pose different levels of difficulties to second language learners. Some of these are naming words that are long and difficult to pronounce or spell, such as:

calorimeter	electromagnet	aluminium	neutralization
carbohydrates	oesophagus	Malpighian layer	seminiferous tubules
epididymis	Eustachian tube	suspensory ligaments	

These terms are particularly prevalent in biology, and one can easily find a long list of them in the index of any biology textbook. Such terms pose a great demand on students' memory capacity and effectively reduce their motivation to learn science. To reduce the problem caused by this, EMI science teachers need the skills that help students master such terms. Furthermore, such terms should only be introduced when necessary. Many of these terms are not required by the curriculum but appear in textbooks, and memorising such terms do not facilitate concept understanding.

Many scientific terms are constructed from prefixes and suffixes. Reference to the structure of these terms allows students to master the spelling of vocabulary in a more meaningful way. Phonics skills can also enable students to understand how to pronounce difficult words. Equipped with these strategies, students may avoid memorising these words by rote.

Some scientific terms are difficult because each of them represent a scientific concept, which denotes specific relationships or a set of characteristics (Wellington, 1994: p.169-170). Understanding of a text composed of these concept terms can be very cognitively demanding. Some concept words are long and difficult, such as: acceleration, electrolysis, crystallisation and irritability. Some refer to abstract concepts that are difficult to imagine or appear to be implausible, such as: inertia, cathode and anode, a frictionless surface, or perfectly elastic particles. Some scientific terms are borrowed from words used in everyday life but with a different meaning, such as: food, particle, force, heat, density and pressure. There is much empirical evidence that such words are common causes of misunderstanding or alternative conceptions in first and second language learners. Results of the present study show that the EMI students have difficulty in mastering the concepts of force, heat and particle nature of matter.

Even non-technical words used in science text are difficult to students. The language used in science textbooks is cognitively demanding because the text is usually loaded with a lot of concept terms and logical connectives (Cassels and Johnstone, 1985; Wellington, 2001). Expressions containing words such as '*therefore*', '*consequently*', '*respectively*' and '*relatively*' convey ideas of causality, sequence and process, which are often not well understood by students.

The above consideration leads to the following recommendation: *Workshops and seminars should be organised to provide science teachers with the knowledge and skills for making the language of science accessible and intelligible to EMI students*. Science teachers who teach in English should be alert to the different levels of cognitive demand of the vocabulary and concept terms encountered in science text, and pay special attention to terms that denote ideas at high levels of abstraction. Teachers may need to spend more time in explaining 'difficult' terms and clarifying abstract concepts or theoretical constructs for students with limited English proficiency.

CONCLUDING REMARKS

The findings made in the present study show that learning science through English has negative effects on the science achievement and self-concept of the EMI students. These negative effects can be related to the limited English proficiency of the students and the inadequate repertoire of instructional strategies used by the science teachers. Recommendations on the implementation of the language policy are proposed in this chapter to address these two problems. If these recommendations are to be adopted, their effectiveness has to be monitored by further research on the science achievement and self-concept of the EMI students, and the range of instructional activities used by teachers in science lessons. The results thus obtained will provide the empirical basis for the policy makers to make informed decisions on how to improve the design of the immersion programme for Hong Kong schools and its process of implementation.

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S1 Science Achievement Test

Part A: This part contains 22 multiple-choice questions. Choose the best answer for each question and mark A, B, C or D on the M.C. Answer Sheet.

1. A beaker contained 200 cm^3 of water. A similar beaker contained 200 cm^3 of petrol. The two beakers were placed on a table near a window on a hot sunny day. A few hours later a student observed that there was less petrol left than water. What does this experiment show?

   A. All liquids evaporate.

   B. Petrol gets hotter than water.

   C. Some liquids evaporate faster than others.

   D. Liquids will only evaporate in sunshine.

2. Which of the following materials can be separated by filtration using a funnel and a piece of filter paper?

   A. A solution of sugar and water

   B. A mixture of alcohol and water

   C. A mixture of mud and water

   D. A mixture of sand and mud

3. Which of the following is a chemical change?

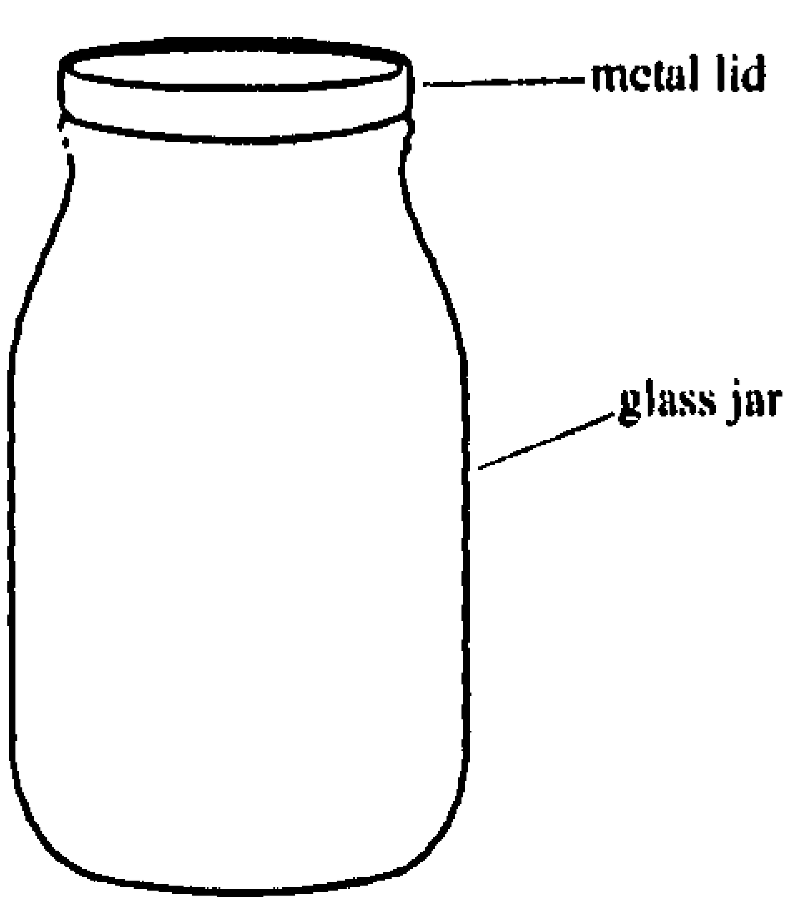
   A. Iron is hammered into a thin sheet.

   B. Wax is heated and turns into a liquid.

   C. Copper turns greenish in the air after a few weeks.

   D. Alcohol is boiled in a test tube.

4. A tight metal lid on a jar may loosen when it has been held in hot water. This is because the hot water causes the



   A. Glass jar to contract.

   B. Metal lid to contract.

   C. Glass jar to expand more than the metal lid.

   D. Metal lid to expand more than the glass jar.

5. A mixture of powdered iron and sulphur is heated. Which of the following will be formed?

   A. a new mixture

   B. two new elements

   C. a solution

   D. a compound

6. When a liquid is transferred from one container to another with a different shape, it

A. Takes the shape of the new container.

B. Evaporates.

C. Changes in volume.

D. Changes in weight.

7. Suppose you want to make some sugar solution. You can use sugar in lumps or in grains. In which one of the following cases would the sugar dissolve fastest?

A. A lump of sugar in cold water.

B. A lump of sugar in hot water.

C. Grains of sugar in cold water.

D. Grains of sugar in hot water.

8. "The solubility of an element X at 25°C is 350 grams per litre." This statement means that at 25°C, no more than 350 g of X will dissolve in every litre of solution. A student added 600 g of X to one litre of water in a beaker at 25°C. Which of the following will happen?

A. All the 600 g will dissolve.

B. 350 g will dissolve and 250 g will settle to the bottom of the beaker.

C. 250 g will dissolve and 350 g will settle to the bottom of the beaker.

D. All of the 600 g will settle to the bottom of the beaker.

9. When two solutions are mixed together, a solid and another solution can form. Look at the table below:

Experiment	Solutions mixed	Results	Solid formed?
I	silver nitrate + sodium chloride	silver chloride + sodium nitrate	Yes
II	copper nitrate + sodium sulphate	copper sulphate + sodium nitrate	No
III	copper sulphate + potassium hydroxide	copper hydroxide + potassium sulphate	Yes
IV	iron suphate + potassium chloride	iron chloride + potassium sulphate	No

Which one below gives the names for the solids formed in Experiments I and III?

	Experiment I	Experiment III
A.	Silver chloride	Copper hydroxide
B.	Sodium nitrate	Potassium sulphate
C.	Potassium sulphate	Silver chloride
D.	Copper hydroxide	Sodium nitrate

10. When a saturated solution cools down, crystals form. Which of the following is INCORRECT?

A. The amount of crystals that form depends on the temperature of the solution.

B. If the solution cools down more quickly, then the crystals are larger.

C. The shape of the crystals that form depends on the type of substance dissolved.

D. If the crystals are filtered, the remaining solution is still saturated.

11. Which of the following is NOT found in the periodic table?

A. water

B. copper

C. oxygen

D. gold

12. When you burn a candle, what happens to the atoms of the candle?

A. The atoms are destroyed.

B. The atoms join together.

C. The atoms change into heat and light.

D. The atoms combine with other atoms in the air.

13. A student held a clean evaporating dish on the top of a yellow Bunsen flame. He found that the bottom of the dish turned black after a few seconds. Which of the following is the correct explanation for this?

A. The flame was too hot.

B. The bottom of the evaporating dish changed into smoke.

C. The flame burnt the evaporating dish and carbon was left.

D. The town gas burnt incompletely and carbon was formed.

14. Gases are more easily compressed than liquids because

A. The gas particles are smaller than liquid particles.

B. The gas particles vibrate faster than liquid particles.

C. The gas particles are lighter than liquid particles.

D. The gas particles are at a greater distance than liquid particles.

15. 2.5 g of salt was dissolved in 10 g of water. A student found that 2 g of the salt solution evaporated. The resulting salt solution would contain

A. 0.5 g of salt and 10 g of water

B. 1.5 g of salt and 9 g of water

C. 2 g of salt and 8.5 g of water

D. 2.5 g of salt and 8 g of water

16. Which of the following plant produces flowers?

A. Grass

B. Pine tree

C. Fern

D. Moss

17. When an iron rod is heated, the iron particles will:

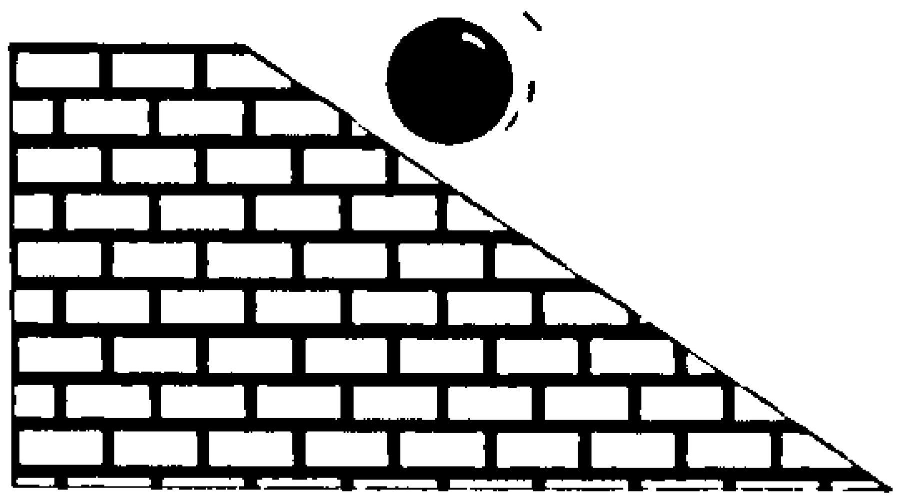
A. get bigger

B. get smaller

C. move closer together

D. move farther apart

18. What energy is the ball gaining when it rolls down?



A. Heat energy

B. Kinetic energy

C. Potential energy

D. Sound energy

19. When an electric torch is turned on, the sequence of energy changes is

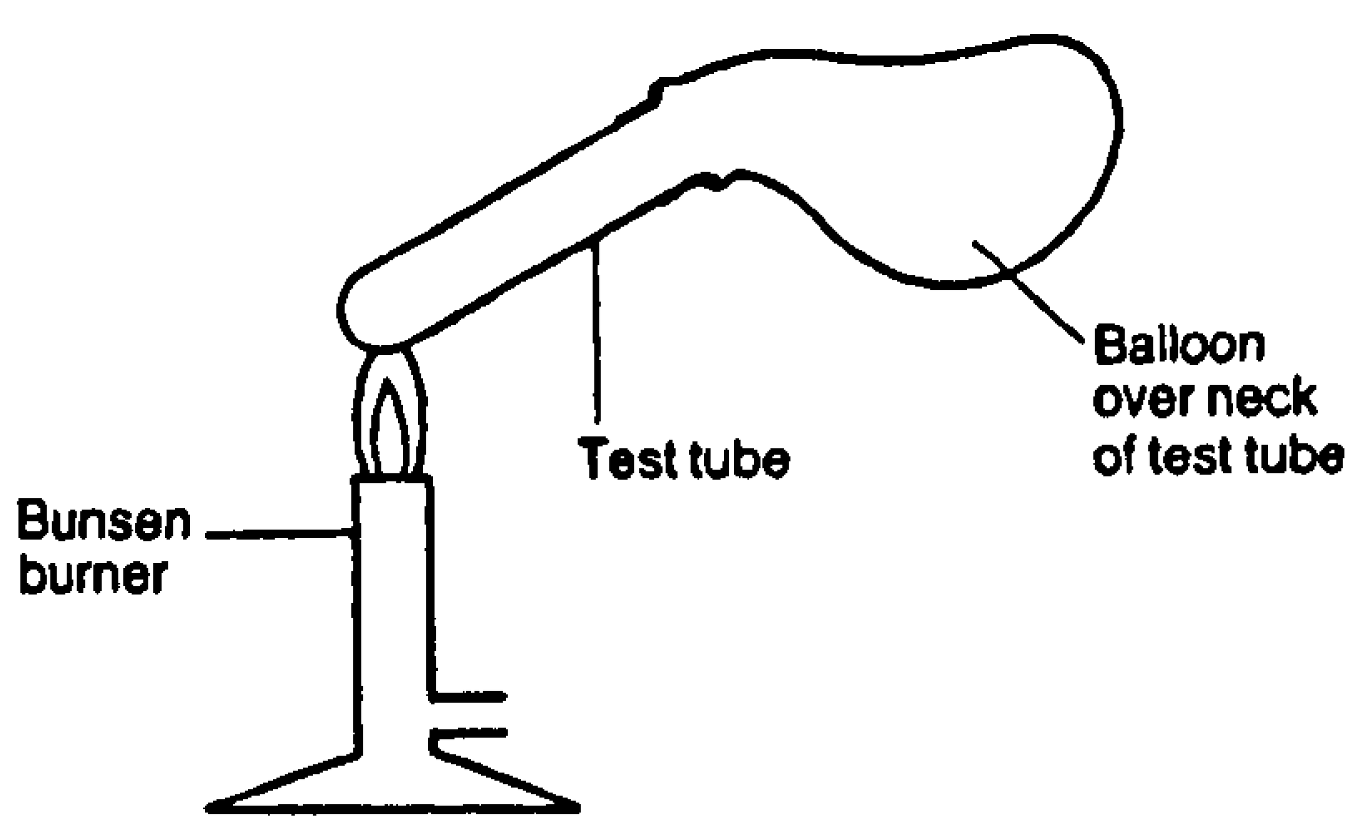
A. potential energy → kinetic energy → light energy

B. kinetic energy → potential energy → light energy

C. chemical energy → electrical energy → light energy

D. heat energy → electrical energy → light energy

20. A balloon is placed over the mouth of a test tube. The test tube is then heated by a flame.



After heating for a short time, the balloon gets bigger. Why does this happen?

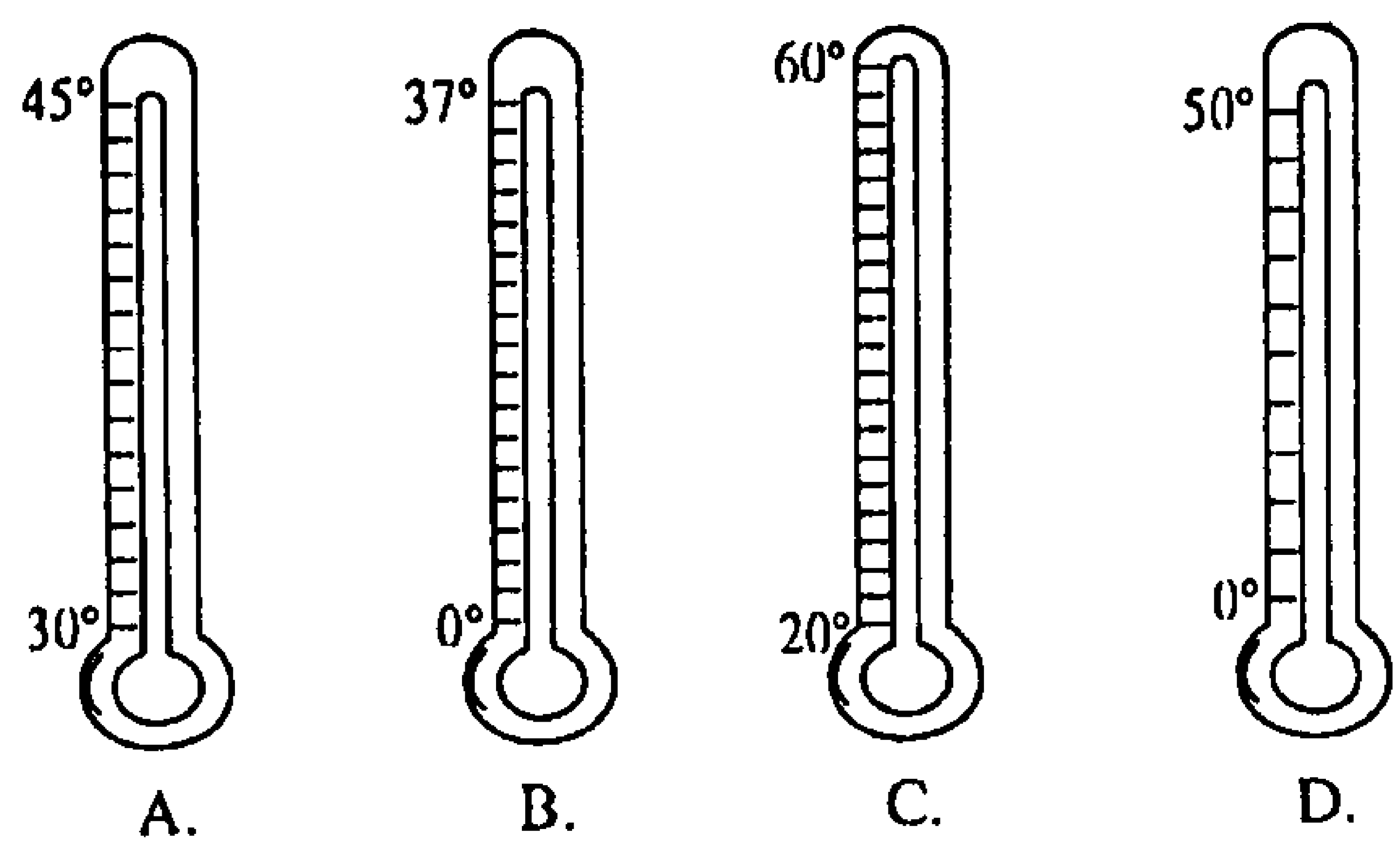
A. The air particles in the tube move faster.

B. The air particles in the tube become bigger.

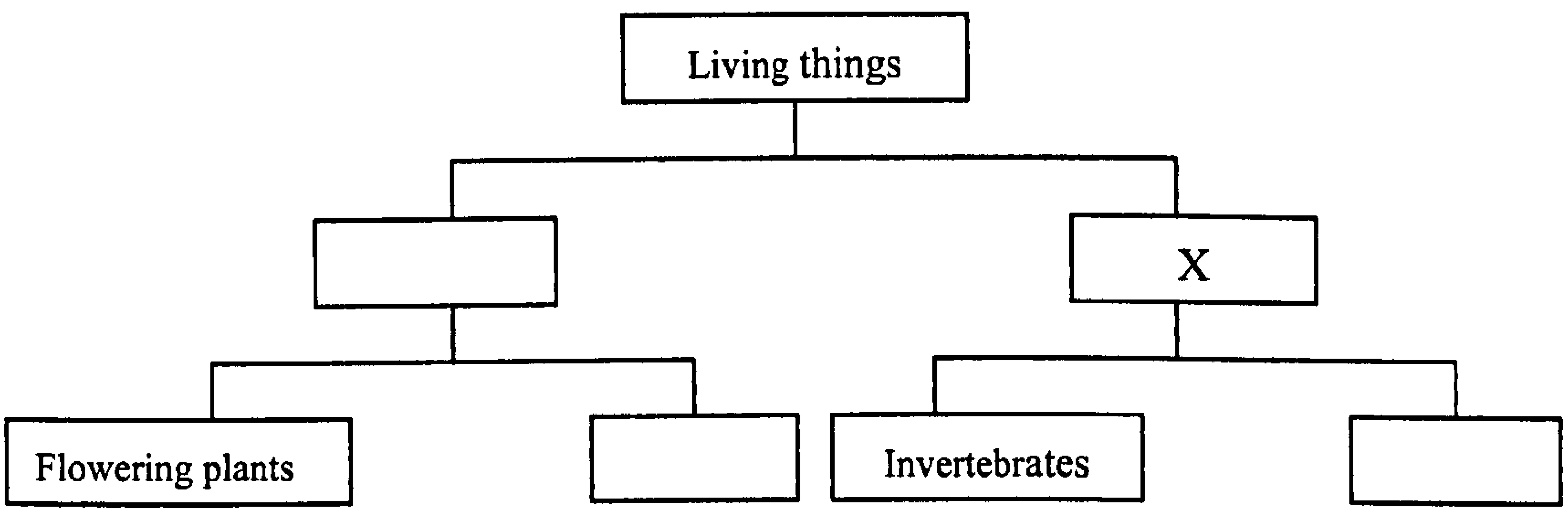
C. The hot air in the test tube rises up.

D. The test tube expands when it is heated.

21. The diagrams show four different Celsius thermometers. Which thermometer would be most suited for accurately measuring body temperature?



22. The diagram below shows a chart for classifying living organisms:



The correct word to insert in box X is

A. vertebrates

B. plants

C. animals

D. dogs

Part B: This part contains 3 free-response questions. Write your answers on this sheet. You are advised to use about 10 minutes to complete this section.

23. Describe TWO ways in which animal cells differ from plant cells.

24. A student did several experiments to break compounds. He found the following results after each compound was heated in a test tube:

Compound	Was carbon dioxide formed?
A. Copper carbonate	Yes
B. Sodium carbonate	No
C. Zinc carbonate	Yes

What can you conclude from his results?

25. Liquid is made up of very small particles. Describe ONE experiment that you could show that there are spaces between the liquid particles.

S2 Science Achievement Test

Part A: This part contains 26 multiple-choice questions. Choose the best answer for each question and mark A, B, C or D on the Multiple Choice Answer Sheet.

1. Which of the following gases is present in the greatest amount in the air that we breathe out?

    A. oxygen

    B. carbon dioxide

    C. nitrogen

    D. water vapour

2. When testing a leaf for starch, why is it necessary to heat the alcohol in a water bath?

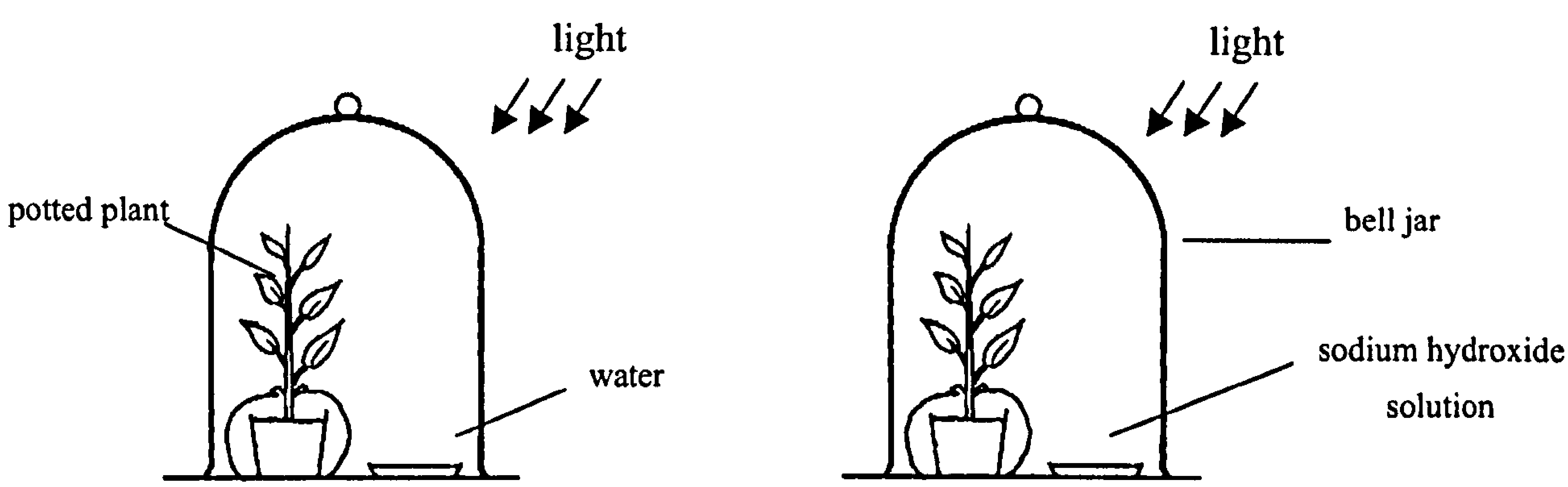
    A.the water bath can keep the alcohol boiling.

    B.the water bath can heat the alcohol more evenly.

    C.in a hot water bath, the alcohol can remove chlorophyll from the leaf faster.

    D.the water bath can prevent the alcohol from catching fire.

Directions: The following two questions refer to the diagram below which shows an experimental set-up.



3. This experiment is designed to show whether photosynthesis requires

    A. air

    B. water

    C. light

    D. carbon dioxide

4. Why is it necessary to keep the plants in the dark for 2 days before the experiment?

    A. To make sure there is a good supply of carbon dioxide.

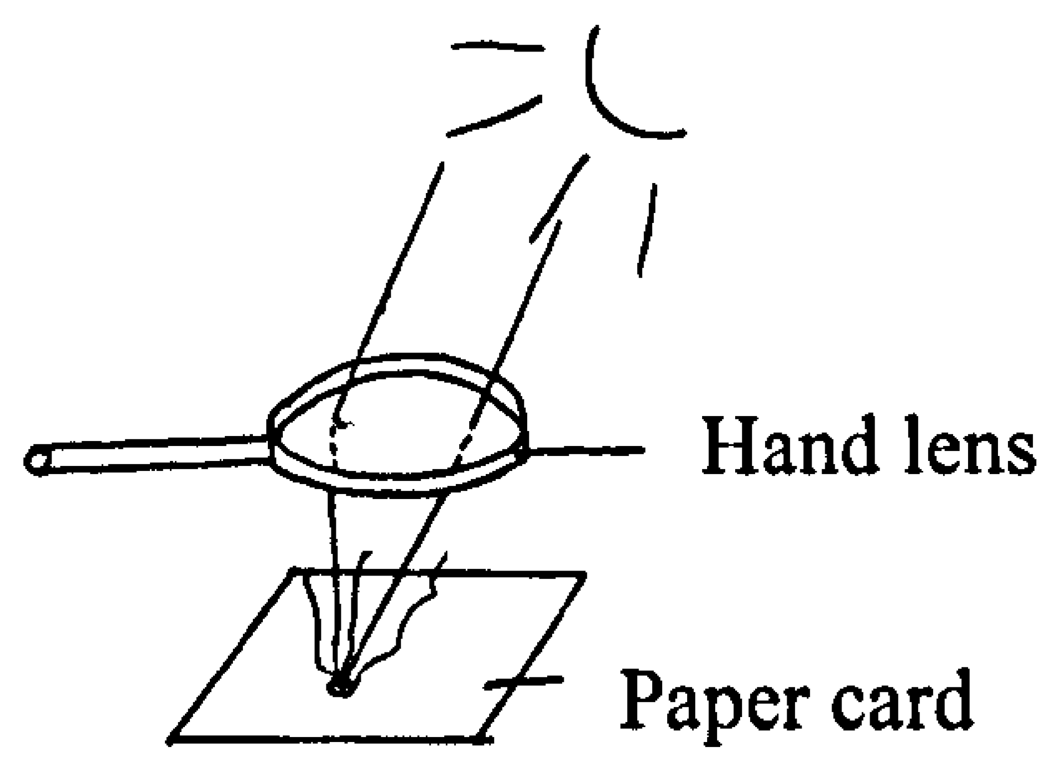
    B. To allow the plants to absorb enough water for photosynthesis.

    C. To allow time for the plants to adapt to the new environment.

    D. To make sure there is no starch in the leaves.

5. Four different paper cards are placed under strong sunlight passing through a lens.

Paper cards	Surface
1	Black dull
2	Black shiny
3	Silver shiny
4	Silver dull



Which paper card will burn the quickest?

A. 1

B. 2

C. 3

D. 4

6. In a cool room, a metal spoon feels colder to touch than a plastic spoon. This is because

A. the metal spoon has a lower temperature than the plastic spoon.

B. metal loses heat more rapidly by radiation than plastic.

C. metal absorbs less heat from the air than plastic.

D. metal is a better conductor of heat than plastic.

7. Which of the following can turn the blue litmus paper red?

(i) milk (ii) orange juice (iii) coca cola

A. (i) and (ii) only

B. (i) and (iii) only

C. (ii) and (iii) only

D. (i), (ii) and (iii)

8. Which of the following problems of vision is caused by a lack of vitamin A in the diet?

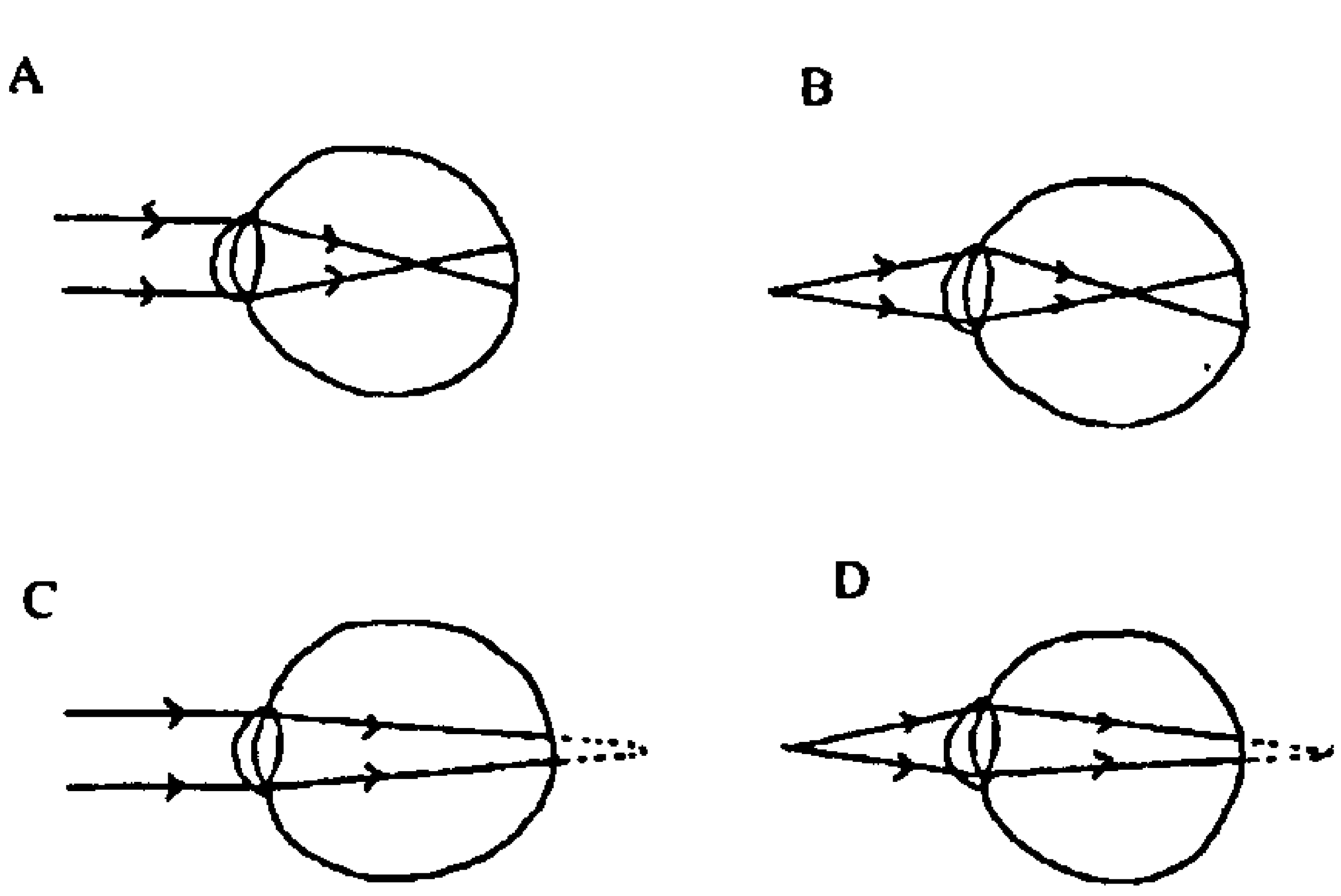
A. Jane cannot see her teacher's writing on the chalkboard.

B. Jane's brother cannot distinguish between red and green colours.

C. Jane's grandma cannot see things in dim light condition.

D. Jane's grandpa cannot read the words in a newspaper held 20 cm away from him.

9. Which of the following diagrams shows a short-sighted condition?



Directions: The following two questions refer to the diagram below which shows parts of a human ear:

10. Which of the following are functions of structure 2?

    (i) to magnify vibrations

    (ii) to transmit vibrations

    (iii) to equalize the pressure on both sides of structure 1

    A. (i) and (ii) only
    B. (i) and (iii) only
    C. (ii) and (iii) only
    D. (i), (ii) and (iii)

11. The function of structures 3 is to
    A. conduct sound vibrations to 4.
    B. detect sound vibrations.
    C. control body balance.
    D. detect body movement.

12. Which of the following is *not* an example of force?

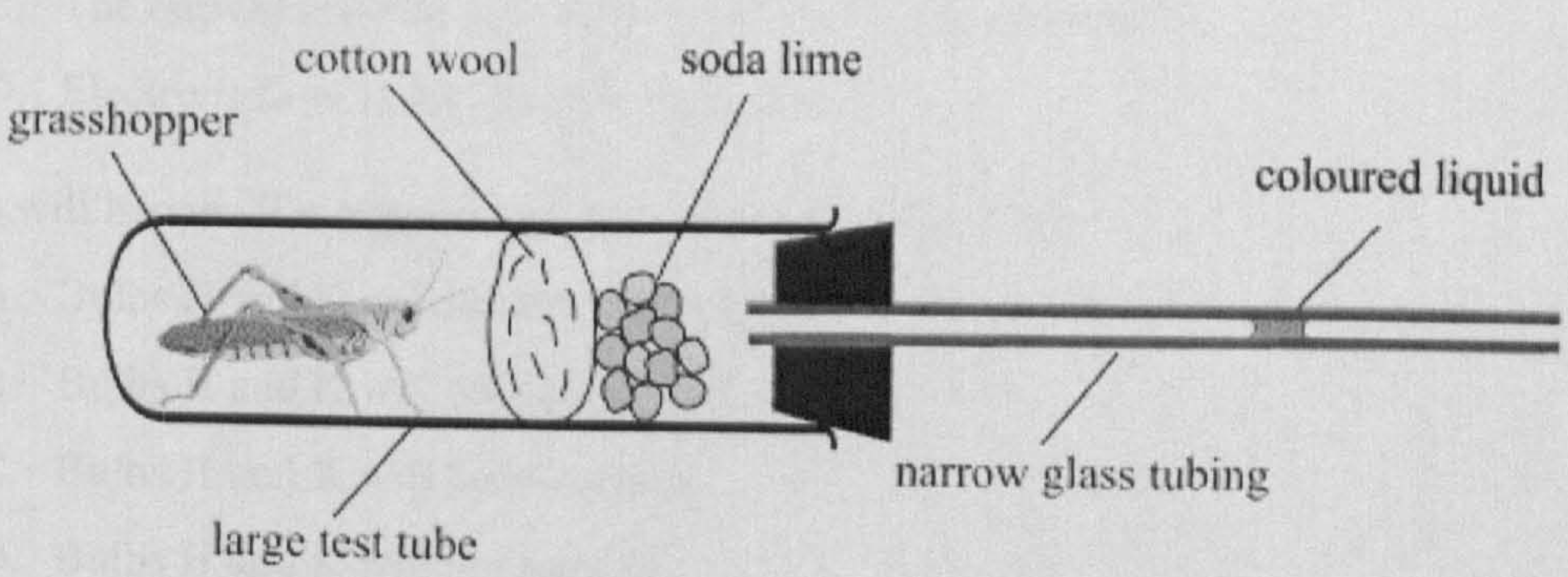
    A. gravity

    B. friction

    C. weight

    D. mass

Directions: The following two questions refer to the diagram below which shows a set-up to measure the respiration rate of a small animal.



13. After some time, the coloured liquid in the narrow tubing moves towards the left hand side. This is because

A. the temperature of the air in the large tube decreases.

B. the animal uses up the oxygen in the large tube.

C. more air is breathed in by the animal than is breathed out.

D. the soda lime absorbs the carbon dioxide given off by the animal.

14. Which of the following can help you to obtain the result more rapidly?

A. Use more soda lime.

B. Use a more narrow glass tubing.

C. Use a larger test tube.

D. Perform the experiment at a higher temperature.

15. Which of the following wire has the highest resistance in an electrical circuit?

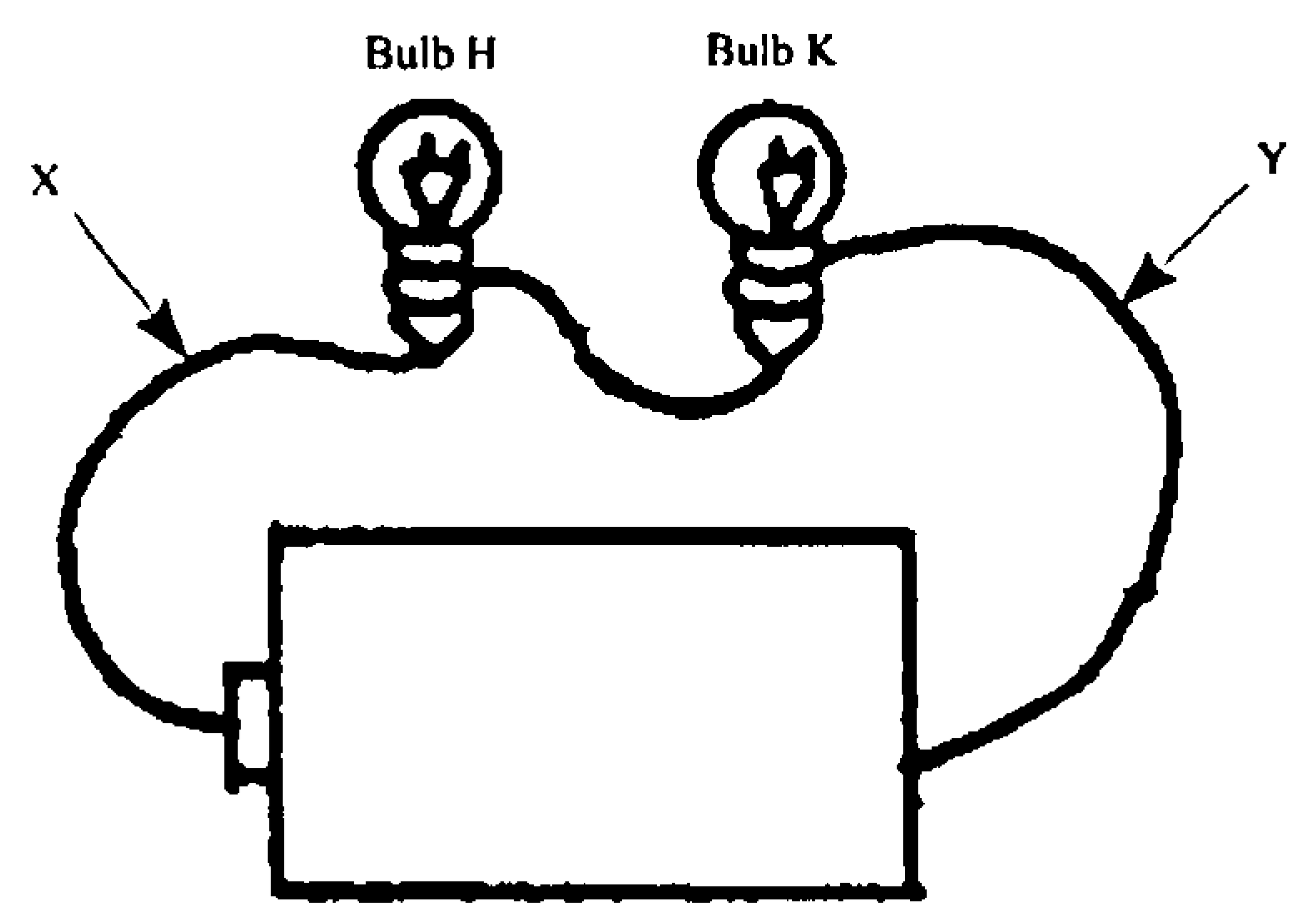
A. A 5 cm-long thin steel wire

B. A 5 cm-long thick steel wire

C. A 10 cm-long thin steel wire

D. A 10 cm-long thick steel wire

Directions: The following two questions refer to the diagram below which shows an electrical circuit with two identical light bulbs.



16. Which of the following is true?

A. Bulbs H and K are equally bright.

B. Bulb H is brighter than bulb K.

C. The current at point X is higher than the current at point Y.

D. Electrons flow along the wire from X to Y.

17. What will happen if a copper wire connects points X and Y?

A. Bulbs H and K will become less bright.

B. Bulbs H and K will become more bright.

C. Bulbs H and K will be burnt out.

D. Bulbs H and K will not light up.

18. The heat from the sun reaches the earth mainly by means of

A. radiation

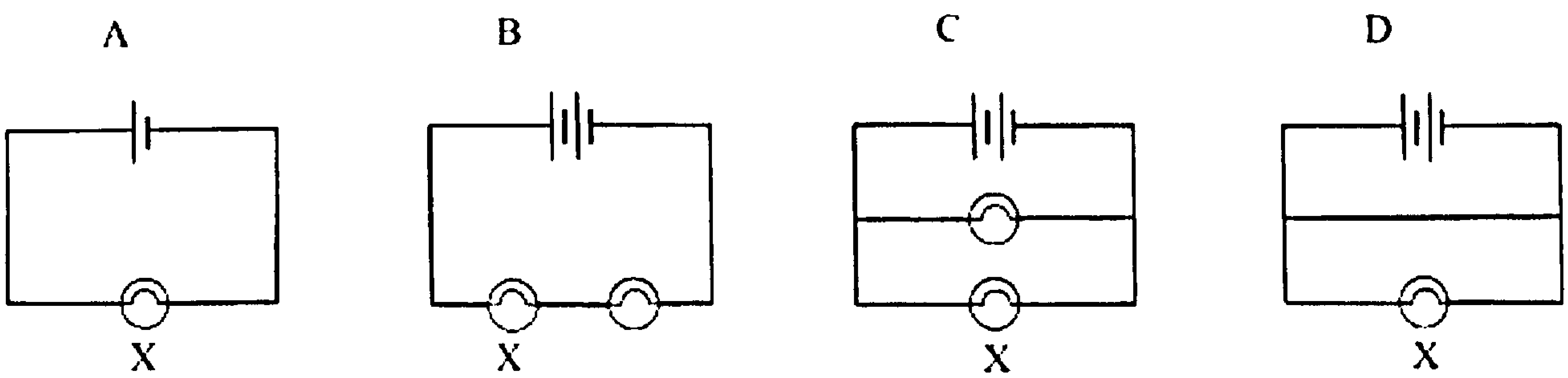
B. conduction

C. convection

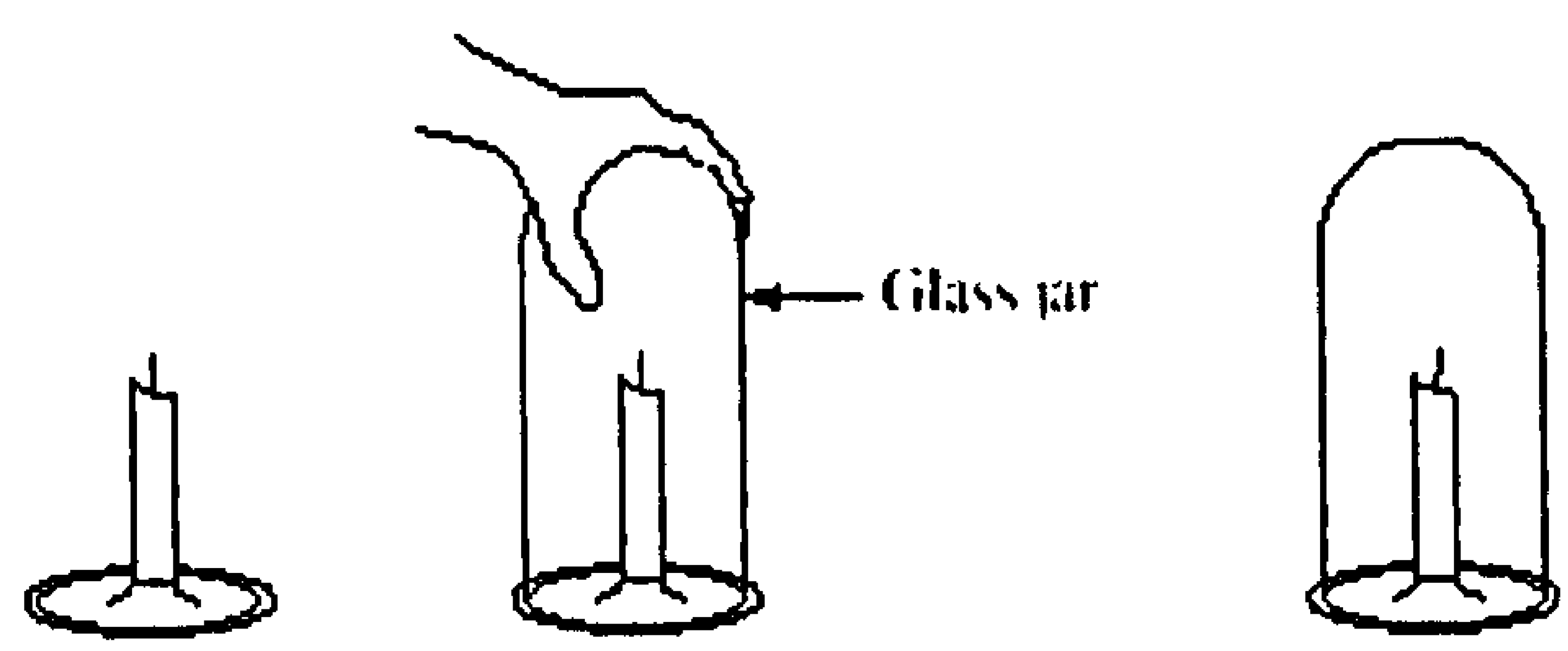
D. nuclear reaction

19. In which of the following circuits will bulb X be brightest?

(The bulbs and batteries used are identical.)



20. When a glass jar is placed over a lighted candle, the flame goes out. This is due to



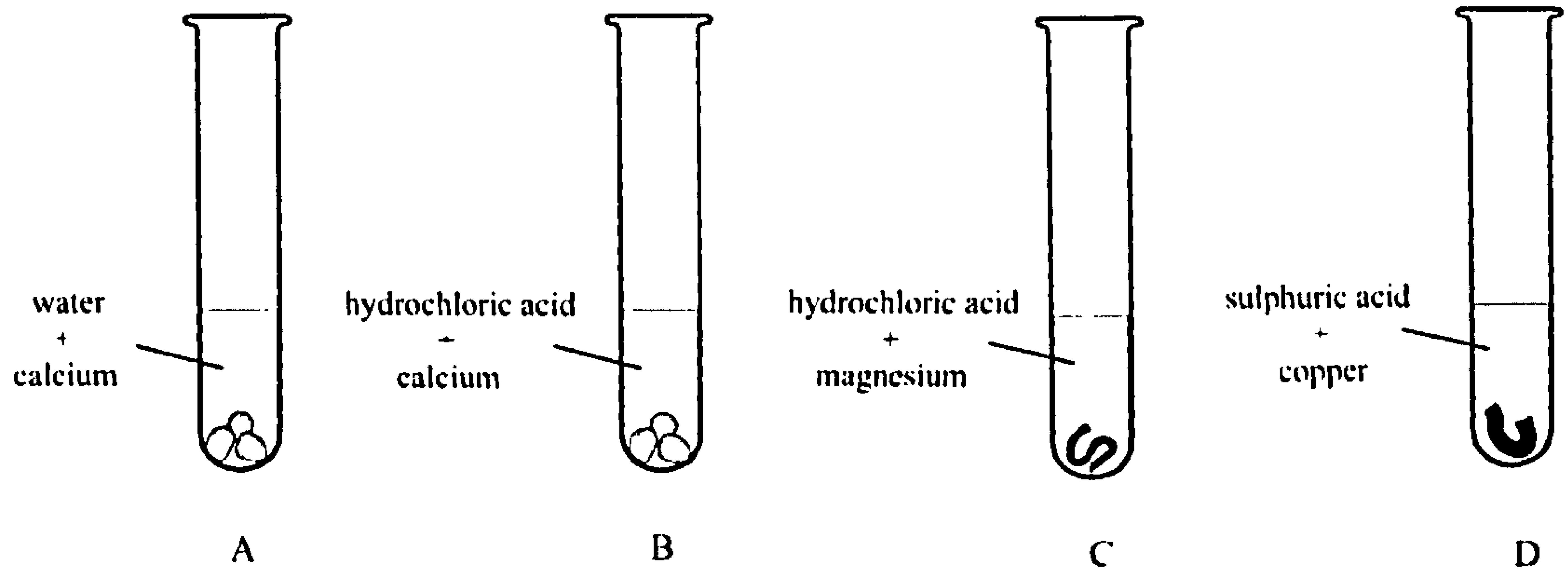
A. formation of water vapour inside the jar.

B. accumulation of carbon dioxide inside the jar.

C. lack of oxygen inside the jar.

D. a very high temperature inside the jar.

21. Which of the following test tubes will give out gas bubbles most rapidly?



22. The gas collected from the above reactions has the following property:

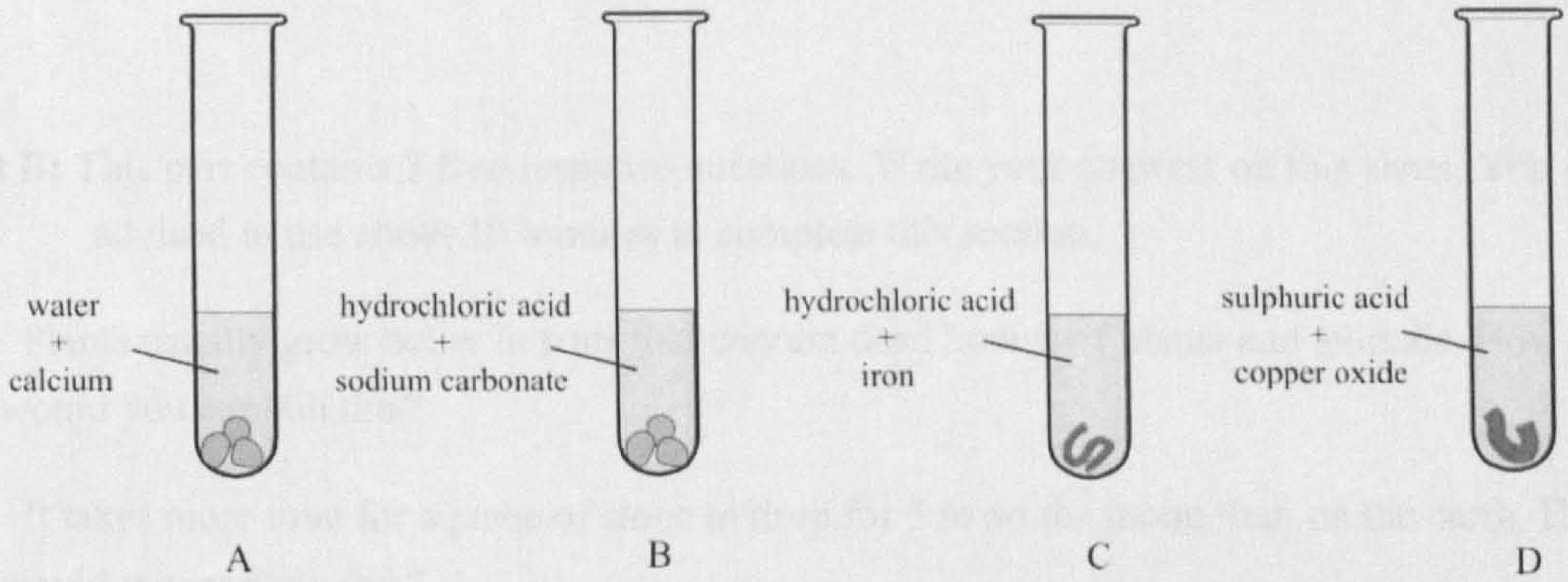
A. It relights a glowing splint.

B. It turns lime water milky.

C. It produces a 'pop' sound when lighted with a burning splint.

D. It is absorbed by sodium hydroxide.

23. At the end of the reaction, which of the following tubes will contain an alkaline solution?



24. Green marine algae (海藻) are mostly found near to the water surface. They are usually absent in ocean water more than 100-metre deep. This is because

A. the green algae have no roots to fix them to the ocean floor.

B. the green algae require a good supply of light for growth.

C. the pressure is too great for the green algae to survive below 100 metres.

D. the green algae would be eaten by animals if they live below 100 metres.

25. Planting trees can help to prevent global warming. This is because

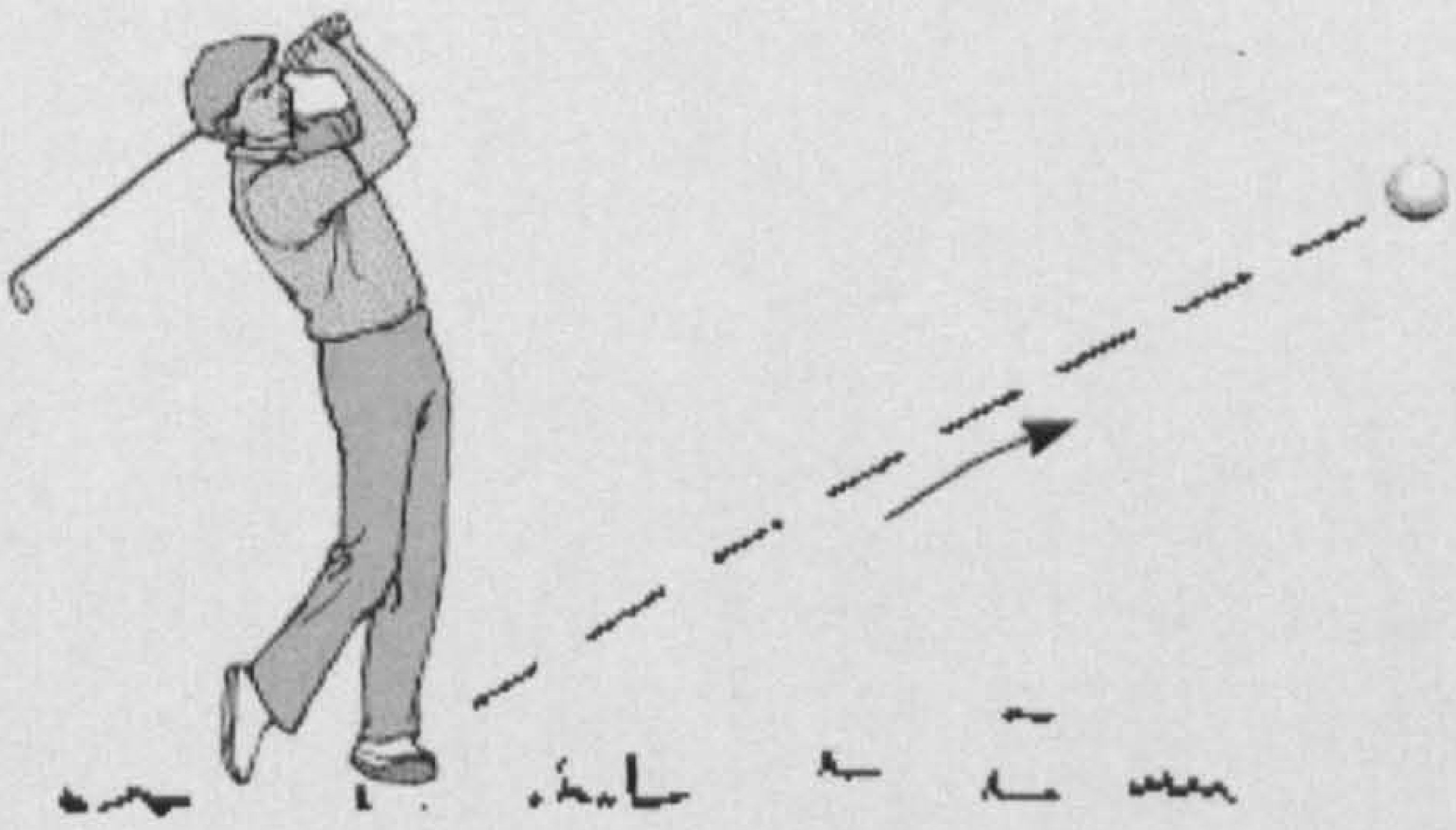
A. sunlight is absorbed by plants for photosynthesis.

B. carbon dioxide in air is used by plants for photosynthesis.

C. evaporation of water from plants cools the air.

D. oxygen produced during photosynthesis forms an ozone layer.

26. A man strikes a golf ball with his racket.



When the ball is moving in air, what are the forces acting on it?

(i) gravity (ii) force from the racket (iii) air resistance

A. (i) and (ii) only

B. (i) and (iii) only

C. (ii) and (iii) only

D. (i), (ii) and (iii)

Part B: This part contains 3 free-response questions. Write your answers on this sheet. You are advised to use about 10 minutes to complete this section.

27. Plants usually grow better in soils that contain dead bodies of plants and animals. How would you explain this?

28. It takes more time for a piece of stone to drop for 5 m on the moon than on the earth. How would you explain this?

29. When a block of ice is covered by a blanket, will the ice melt faster or slower in a room with an air temperature of 25°C? Why?

S3 Science Achievement Test

Part A: This part contains 30 multiple-choice questions. Choose the best answer for each question and mark A, B, C or D on the Multiple Choice Answer Sheet.

1. Which part of the tooth contains pain receptors?

   A. enamel

   B. cement

   C. pulp cavity

   D. root

2. Which of the following does NOT contain any digestive enzymes?

   A. saliva

   B. gastric juice

   C. bile juice

   D. pancreatic juice

3. Which of the following food substances can provide energy to our body?

   (i) carbohydrate (ii) fat (iii) protein

   A. (i) and (ii) only

   B. (i) and (iii) only

   C. (ii) and (iii) only

   D. (i), (ii) and (iii)

4. Which of the following mineral salts are required in the diet to keep our body healthy?

   (i) nitrate salts (ii) iron salts (iii) calcium salts

   A. (i) and (ii) only

   B. (i) and (iii) only

   C. (ii) and (iii) only

   D. (i), (ii) and (iii)

5. Which of the following is an example of chemical change?

   A. melting ice

   B. rusting iron

   C. dissolving sugar in water

   D. petroleum evaporating into air

6. Extraction of iron is usually achieved by heating the iron oxide with

A. sulphur

B. oxygen

C. carbon

D. hydrogen

7. Which of the following organs are involved in the digestion of food in a mammal?

(i) liver (ii) kidney (iii) pancreas (iv) spleen

A. (i) and (ii) only

B. (i) and (iii) only

C. (ii) and (iv) only

D. (iii) and (iv) only

8. Which of the following is an excretory product of our body?

A. carbon dioxide

B. nitrogen

C. glucose

D. dietary fibre

9. Which of the following substances are usually present in the urine of a healthy person?

(i) urea (ii) mineral salts (iii) proteins

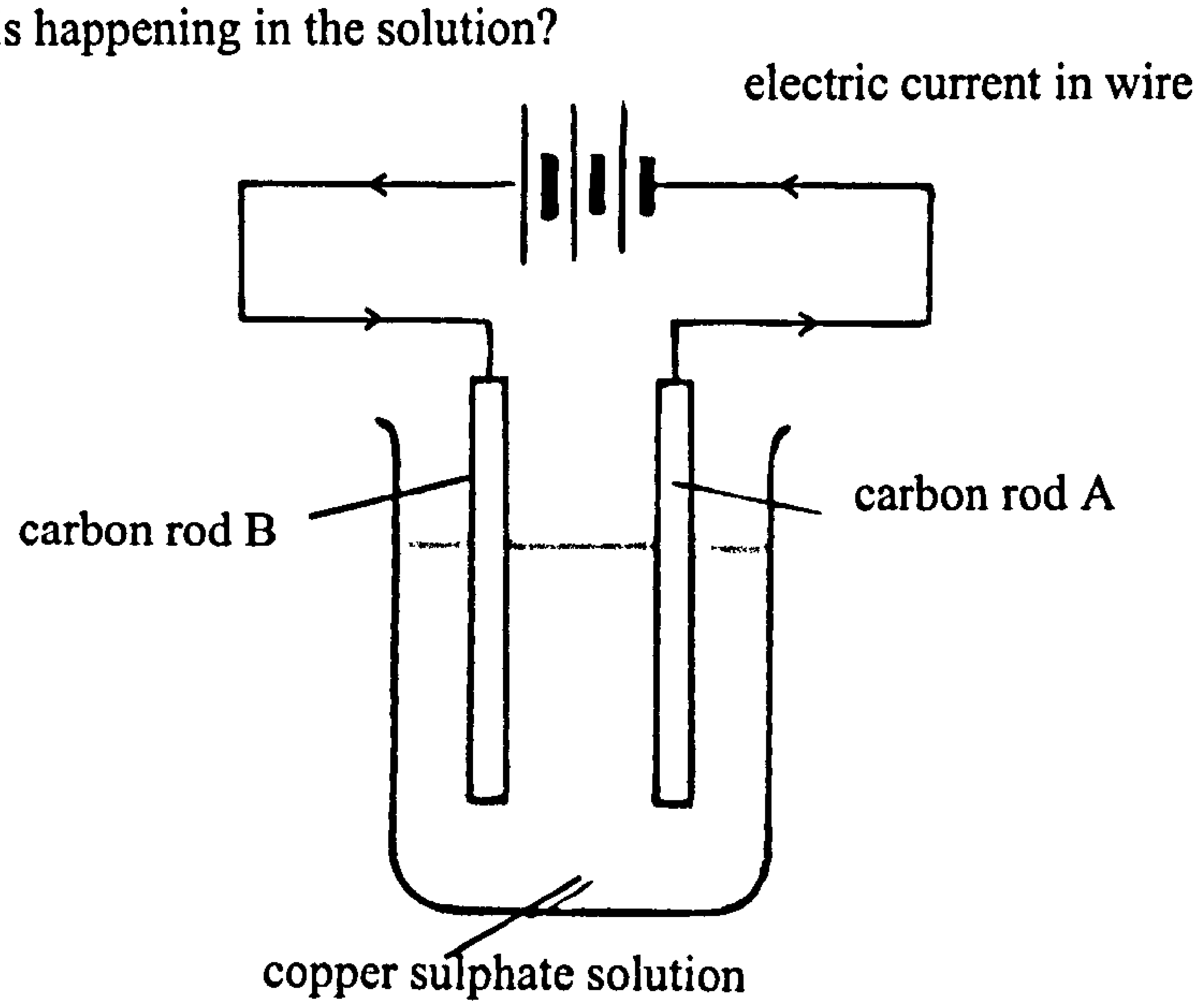
A. (i) and (ii) only

B. (i) and (iii) only

C. (ii) and (iii) only

D. (i), (ii) and (iii)

10. The diagram below shows an electric circuit for electrolysis. When there is a current in the wire, what is happening in the solution?



A. Copper ions gain electrons from rod A.

B. Copper ions gain electrons from rod B.

C. Electrons go through the solution from rod A to rod B.

D. Electrons go through the solution from rod B to rod A.

11. Which of the following will give a golden yellow flame in the flame test?

A. copper compounds

B. iron compounds

C. sodium compounds

D. potassium compounds

12. In Hong Kong, which of the following is added to drinking water to prevent tooth decay?

A. iodide

B. fluoride

C. sulphide

D. chloride

13. Which of the following is a use of sodium hydroxide?

A. making bleaches

B. making pesticides

C. making soaps

D. making glass

14. A polythene rod is rubbed with a dry cloth. The rod becomes negatively charged because

A. electrons are removed from it.

B. electrons are added to it.

C. protons are removed from it.

D. protons are added to it.

15. Which of the following ways of transmitting electricity can reduce energy loss?

A. low voltage and small current

B. low voltage and large current

C. high voltage and small current

D. high voltage and large current

16. A person cannot see clearly in dim light conditions. Which of the following food is most effective in helping him to restore his vision in dim light conditions?

A. beef

B. bread

C. carrot

D. lemon

17. Food substances absorbed into the blood of the small intestine is first transported to

A. the liver

B. the heart

C. the kidney

D. the pancreas

18. All cells in a flowering plant, such as the epidermal cells, xylem cells and mesophyll cells, have

A. a nucleus.

B. a cell membrane.

C. a cell wall.

D. chloroplasts

19. Comparing with arteries, veins always contain blood with

A. a lower oxygen content.

B. a higher carbon dioxide content.

C. a lower food content.

D. a lower blood pressure.

20. The most common non-metal element in the earth's crust is

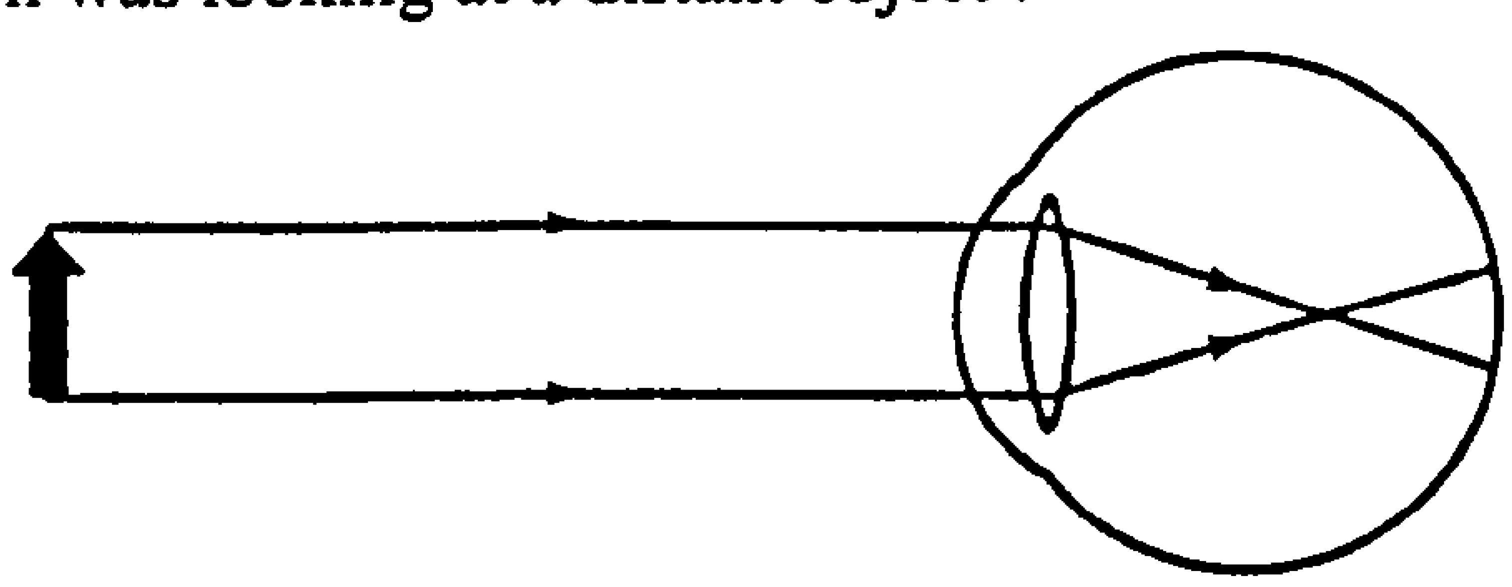
A. nitrogen

B. oxygen

C. carbon

D. sulphur

21. The diagram below was drawn by a student to show the path of light rays when a short-sighted person was looking at a distant object :



What is wrong with this diagram ?

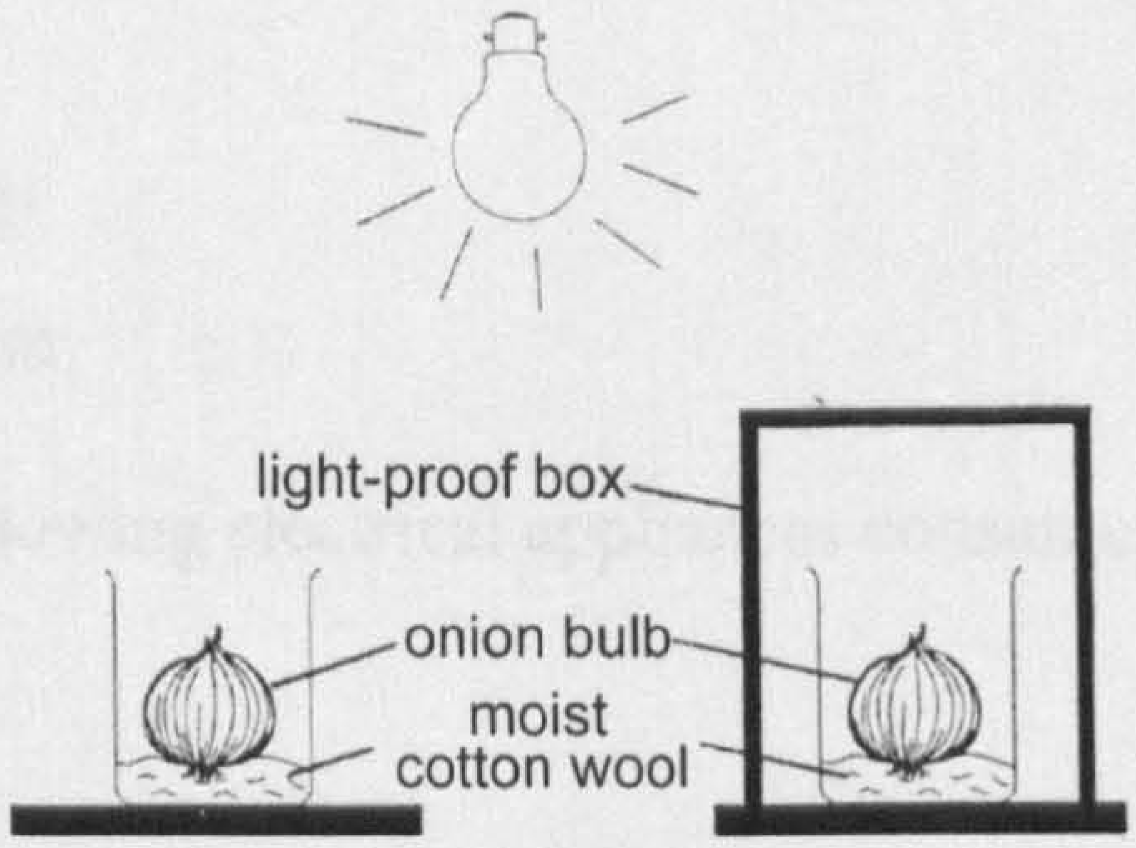
A. The rays should be focused on the retina.

B. The rays should be focused behind the retina.

C. The rays from the object should be diverging.

D. The object should not be shown.

Directions : Questions 22 and 23 refer to the diagram below, which shows a set-up used by Eric in an experiment. After one week, he noted whether the onion bulb in each beaker had germinated into a new plant.



22. This experiment was designed to find out whether the development of new plants from the onion bulbs required

    A. light.

    B. water.

    C. light and water.

    D. light or water.

23. If the onion bulbs in both beakers germinate after one week, what conclusion can be drawn?

    A. Light is not necessary for the germination of onion bulbs.

    B. Water is necessary for the germination of onion bulbs.

    C. Either light or water is necessary for the germination of onion bulbs.

    D. No conclusion can be drawn.

24. A man can jump higher on the moon than on the earth because

    A. there is no air on the moon.

    B. his body has a smaller mass on the moon.

    C. his body has less energy on the moon.

    D. the force of gravity on the moon is smaller.

25. Xylem vessels in plants are responsible for the transport of

    A. water and carbon dioxide

    B. water and mineral salts

    C. oxygen and carbon dioxide

    D. oxygen and mineral salts

26. Which of the following plants does not bear flowers but reproduces by seeds?

    A. fern

    B. pine

    C. grass

    D. broad bean

27. Which of the following metals is most reactive with oxygen?

A. iron

B. copper

C. aluminium

D. magnesium

28. Which of the following electrical appliances consumes the largest amount of electrical energy?

A. a fan

B. a computer

C. a television

D. an electrical heater

29. Extraction of very reactive metals, such as sodium and magnesium, from their compounds can be done by

A. electrolysis

B. carbon reduction

C. heating with hydrogen

D. physical method

30. Which of the following mixtures produces hydrogen?

A. zinc and hydrochloric acid

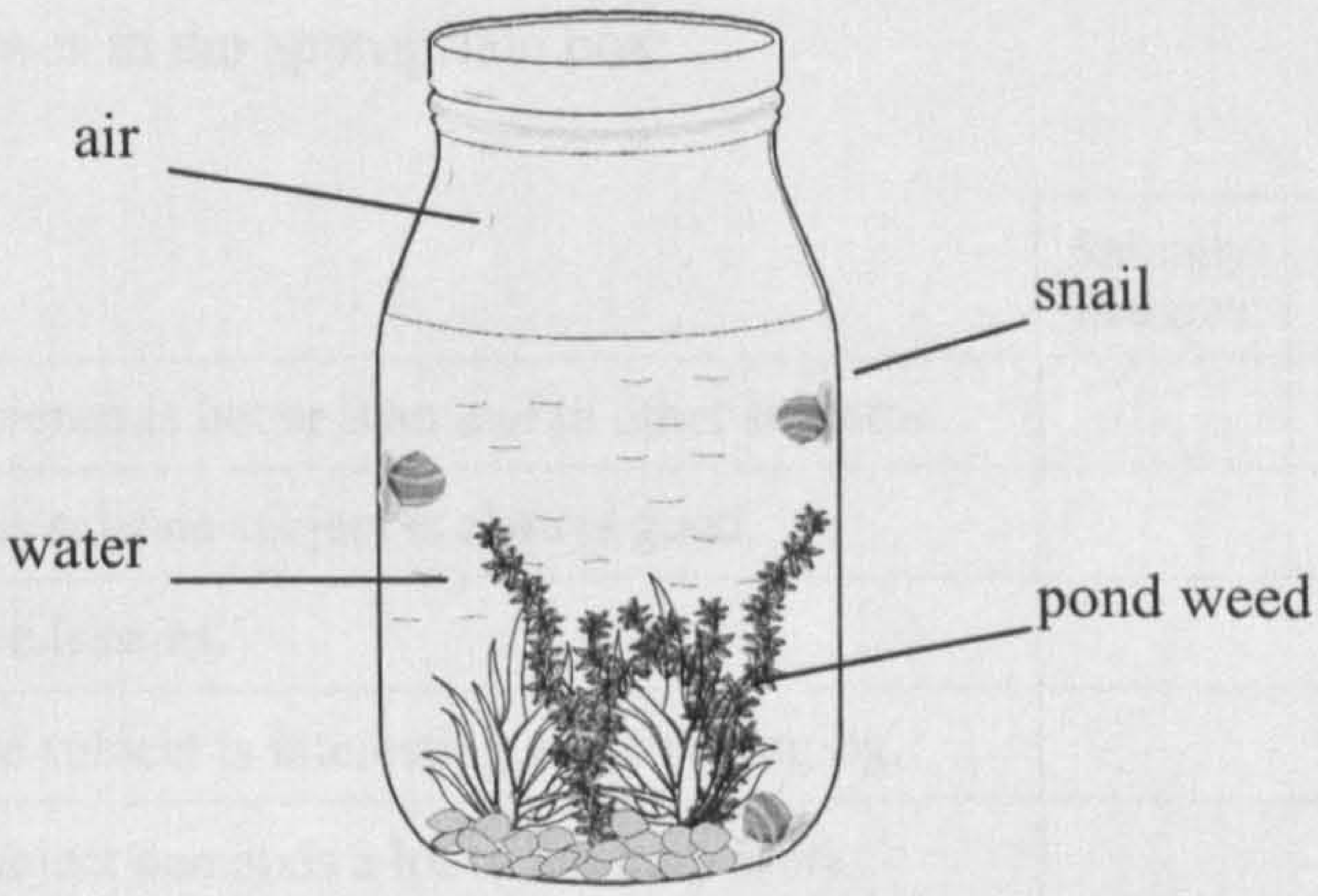
B. magnesium and water

C. silver and steam

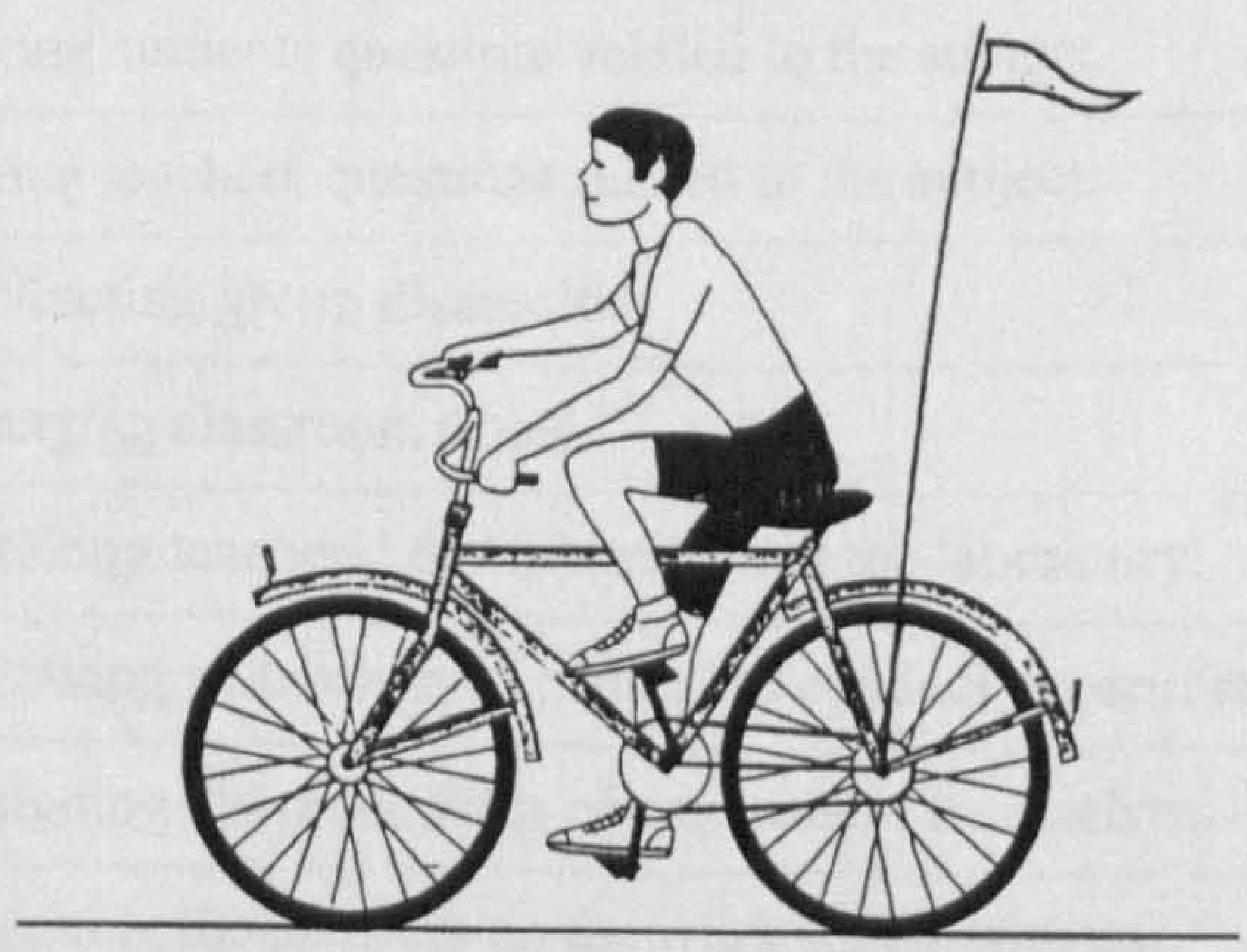
D. copper and sulphuric acid

Part B: This part contains 3 free-response questions. Write your answers on this sheet. You are advised to use about 10 minutes to complete this section.

31. The glass bottle shown below contains some pond weeds and snails. When the bottle is put under light, the organisms inside the bottle can live for many years. Explain why it is important to put the bottle under light.



32. The picture below shows a boy sitting on a bicycle. He is not pedalling and not using the brake, and the bicycle is slowing down.



Are there any forces acting on the bicycle? Explain your answer.

33. When water boils in a beaker, big bubbles appear. What do you think is in the bubbles? How are they formed?

Questionnaire on students' self-conception and perception of mode of Instructional activities in Science lesson

Please mark your answer in the appropriate box:

		Strongly disagree	Disagree	Agree	Strongly agree
1.	My achievement in science is better than that in other subjects.				
2.	My performance in the science subject is always good.				
3.	I like attending science lessons.				
4.	I think that the science subject is interesting and challenging.				
5.	I think that science subject demands a lot of memory work.				
6.	I think that the science subject is easy.				
7.	I understand the explanation of my science teacher.				
		Never	Rarely	Sometimes	Always
8.	Students listening to teachers' explanation of subject content.				
9.	Teachers asking students questions related to the subject.				
10.	Students asking teachers questions related to the subject.				
11.	Students conducting group discussion.				
12.	Teacher managing classroom order.				
13.	Students watching teachers' demonstration in the laboratory.				
14.	Students following instruction of manual to conduct experiments.				
15.	Students designing the procedures of experiment themselves.				
16.	Teachers checking the answers on the work sheets with us.				

Science Lesson Evaluation Guide

	1	3	5
Teaching style:			
Pupils listen to teacher's explanation/instruction	☐	☐	☐
Continuous attention and motivation	☐	☐	☐
Teacher checks answers on worksheet with pupils	☐	☐	☐
Pupils attentive and keen	☐	☐	☐
Pupils ask questions on lesson content	☐	☐	☐
Use of interactive activities	☐	☐	☐
Questioning skills:			
Teacher asks questions on recall	☐	☐	☐
Teacher asks questions to assess understanding	☐	☐	☐
Teacher asks high-order questions	☐	☐	☐
Use of probing to improve pupils' responses	☐	☐	☐
Pupils give long, thoughtful responses to questions	☐	☐	☐
Pupils respond actively to questions	☐	☐	☐
Communication skills:			
Language suitable and accurate	☐	☐	☐
Quality of explanations	☐	☐	☐
Mobility in classroom	☐	☐	☐
Non-verbal communication to convey warmth	☐	☐	☐
Watchful on all parts of classroom	☐	☐	☐
Energetic and enthusiastic	☐	☐	☐

Scoring: 1 = rarely/weak, 3 = satisfactory, 5 = always/good

Effects of sampling strata on S2 science achievement scores with two versions of test papers for the EMI students

(a) Bilingual paper

	Null-Model			Model 1		
Fixed Effects	Estimate	Standard Error		Estimate	Standard Error	
Pupil Level (L1)						
Intercept	0.473*	0.050		0.176*	0.045	
AAI				0.553*	0.019	
School Level (L2)						
CHIG Effects on						
S2 Science Intercept				0.522*	0.069	
CMID Effects on						
S2 Science Intercept				0.313*	0.086	
CLOW Effects on						
S2 Science Intercept				0.521*	0.074	
Random Effects	Estimate	df	Chi-square	Estimate	df	Chi-square
L-1 Variance (σ^2)	0.760			0.701		
% of L-1 σ^2 Explained				7.76%		
L-2 Variance (σ^2)	0.243	99	4795.841	0.069	96	832.574
% of L-2 σ^2 Explained				71.53%		

Note: * Significant at the 0.05 level

(b) English paper

	Null-Model		Model 1	
Fixed Effects	Estimate	Standard Error	Estimate	Standard Error
Pupil Level (L1)				
Intercept	0.407*	0.050	-0.240*	0.063
AAI			0.558*	0.021
School Level (L2)				
CHIG Effects on				
S2 Science Intercept			0.839*	0.081
CMID Effects on				
S2 Science Intercept			0.625*	0.096
CLOW Effects on				
S2 Science Intercept			0.816*	0.087

Random Effects	Estimate	df	Chi-square	Estimate	df	Chi-square
L-1 Variance (σ^2)	0.794			0.731		
% of L-1 σ^2 Explained				7.90%		
L-2 Variance (σ^2)	0.242	99	4165.488	0.075	96	695.964
% of L-2 σ^2 Explained				68.89%		

Note: * Significant at the 0.05 level

Effects of sampling school strata on S1 Science Achievement Test

	Null-Model		Model 2	
Fixed Effects	Estimate	Standard Error	Estimate	Standard Error
Pupil Level (L1)				
Intercept	-0.056	0.058	-0.597 *	0.107
Individual AAI			0.508 *	0.021
Female			0.070 *	0.016
Individual SES			0.008	0.006
School Level (L2)				
Mean-AAI Effects on				
S1 Science Intercept			0.235	0.097
Mean-SES Effects on				
S1 Science Intercept			-0.072	0.075
Mean-CHIG Effects on				
S1 Science Intercept			0.706 *	0.079
Mean-CMID Effects on				
S1 Science Intercept			0.572 *	0.129
Mean-CLOW Effects on				
S1 Science Intercept			0.803 *	0.234

Random Effects	Estimate	df	Chi-square	Estimate	df	Chi-square
L-1 Variance (σ^2)	0.802			0.586		
% of L-1 σ^2 Explained				26.933 %		
					6	
L-2 Variance (σ^2)	0.552 *	89	7246.120	0.054 *	6	382.675
% of L-2 σ^2 Explained				90.217 %		

Note: * Significant at the 0.05 level

Effects of sampling school strata on S2 Science Achievement Test scores

	Null-Model		Model 2	
Fixed Effects on intercept	Estimate	Standard Error	Estimate	Standard Error
Pupil Level (L1)				
Intercept	-0.064	0.048	-0.483 *	0.113
Individual AAI			0.384 *	0.017
Female			-0.080 *	0.016
Individual SES			0.003	0.007
School Level (L2)				
Mean-AAI Effects on				
S2 Science Intercept			0.196	0.106
Mean-SES Effects on				
S2 Science Intercept			0.047	0.074
Mean-CHIG Effects on				
S2 Science Intercept			0.627 *	0.088
Mean-CMID Effects on				
S2 Science Intercept			0.483 *	0.141
Mean-CLOW Effects on				
S2 Science Intercept			0.777 *	0.235

Random Effects	Estimate	df	Chi-square	Estimate	df	Chi-square
L-1 Variance (σ^2)	0.675			0.638		
% of L-1 σ^2 Explained				5.449 %		
L-2 Variance (σ^2)	0.214 *	94	5269.437	0.080 *	69	382.665
% of L-2 σ^2 Explained				62.693 %		

Note: * Significant at the 0.05 level

Effects of sampling school strata on S3 Science Achievement Test

	Null-Model		Model 2	
Fixed Effects on intercept	Estimate	Standard Error	Estimate	Standard Error
Pupil Level (L1)				
Intercept	-0.054	0.053	-0.451 *	0.121
Individual AAI			0.290 *	0.018
Female			0.124 *	0.021
Individual SES			-0.013	0.007
School Level (L2)				
Mean-AAI Effects on				
S3 Science Intercept			0.314 *	0.095
Mean-SES Effects on				
S3 Science Intercept			0.037	0.069
Mean-CHIG Effects on				
S3 Science Intercept			0.270 *	0.114
Mean-CMID Effects on				
S3 Science Intercept			0.464 *	0.129
Mean-CLOW Effects on				
S3 Science Intercept			0.683 *	0.247

Random Effects	Estimate	df	Chi-square	Estimate	df	Chi-square
L-1 Variance (σ^2)	0.666			0.642		
% of L-1 σ^2 Explained				3.618 %		
L-2 Variance (σ^2)	0.259 *	91	5987.826	0.141 *	67	638.307
% of L-2 σ^2 Explained				45.604 %		

Note: * Significant at the 0.05 level