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Evaluation of the Effects of the Medium of Instruction on Science Learning of Hong Kong Secondary Students: Instructional Activities in Science Lessons

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This article reports part of the findings of a longitudinal study on the effects of a language policy implemented in 1998 on the science learning of junior secondary students. It focuses on the effects of the instructional medium on the instructional activities in science lessons. According to students' responses to a questionnaire, EMI (English as the medium of instruction) teachers tended to adopt a more didactic approach and use less interactive activities than CMI (Chinese as the medium of instruction) teachers. In practical work, EMI students had fewer opportunities to design investigations, but tended to follow prescribed instructions. These findings are consistent with the observations on science lessons. In comparison with CMI teachers, EMI teachers spent more time on instruction and checking answers with their students, but seldom asked questions to assess students' understanding or higher cognitive skills. While EMI students were passive and quiet during lessons, CMI students were more active in answering or raise questions. By

using short, disjointed sentences, EMI teachers often failed to communicate abstract or complex concepts accurately. To resolve these problems, EMI teachers need to master the skills to express cognitively demanding concepts through context-embedded language, and to facilitate students to acquire science knowledge while building their language skills. It is also helpful to allow more time for the transition from CMI to EMI.

Implementation of a New Language Policy for Schools

Before 1998, secondary schools in Hong Kong were free to choose the language medium for their students. Due to the great societal demand for graduates with high English proficiency, over 90% of secondary schools opted for English, a second language, as the medium of instruction (EMI). The remaining schools opted for Chinese, the mother tongue, as the medium of instruction (CMI). It was hoped that, through such an immersion approach in a second language, EMI students could develop high levels of English proficiency essential for employment and further academic studies.

There is, however, ample evidence indicating that many EMI students did not learn effectively in English, and failed to develop adequate English proficiency through immersion in English (e.g., Brimer et al., 1985; Hirvela & Law, 1991; Johnson, Chan, Lee, & Ho, 1985). These problems were thought to have been incurred by the unregulated use of EMI in schools. In order to ensure that most students can benefit from mother tongue teaching, and that only students with adequate English proficiency could receive instruction through English, the government enforced 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 this policy are spelt out as follows (Education Department, 1997):

> With the use of Chinese as MOI [medium of instruction] 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. (para. 1.3)

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 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 CMI students can learn academic subjects effectively in their mother tongue. For a better understanding of the rationale and background of the new language policy, reference can be made to a comprehensive review of studies on the issue of MOI in Hong Kong schools made by Yip, Tsang, and Cheung (2003).

Outline of the Study on Science Learning

In order to explore the impact and implications of the new language policy on MOI on student learning as set out in the *Guidance*, a 3-year project was launched in 1999. The study compares the achievement of EMI and CMI students in Chinese, English, Mathematics, Social Studies, and Science in 100 sampled schools. The present study, as a part of this main project, focuses on the effects of MOI on science learning. An important outcome of science learning is students' academic achievement in science, which was assessed by a written test near the end of each academic year in Secondary 1, 2, and 3. The findings on the effects of MOI on science achievement as measured by the science achievement tests have been reported in a previous paper (Yip et al., 2003). The analysis indicated that EMI students performed much less satisfactorily in the science achievement test than their CMI counterparts, after taking account of their prior academic ability as well as other student and school variables. EMI students were found to be particularly weak in items that involved high-order thinking, application of scientific knowledge, and understanding of science terminology.

Building on prior research, this article explores learning and teaching processes rather than learning outcomes. The study is guided by the following research questions:

1. What are the characteristics of instructional activities taking place in science lessons of EMI and CMI schools?
2. How are these characteristics related to the effects of different MOI on science achievement (Yip et al., 2003)?

Methodology: Quantitative and Qualitative Measures

Two tools were used to collect data on the instructional activities in science lessons in this study: student questionnaire and lesson observation schedule. The questionnaire was completed by Secondary 2 (equivalent to Grade 8) students of 100 secondary schools representative of the school population of Hong Kong while classroom observation was conducted in 10 schools.

Students' Perceptions of Classroom Climate

The present study involved 17,616 students from 100 secondary schools selected by a stratified random sampling method so that they represented the student population of Hong Kong. The first stratum for sampling is the MOI streaming: 25 and 75 schools were selected randomly from EMI schools and CMI schools respectively. The CMI schools were then stratified into high, medium, and low abilities (i.e., CHIG, CMID, and CLOW strata) according to the mean academic ability of their Secondary 1 intake.

This student cohort completed a questionnaire containing nine items that collate students' perceptions of instructional activities in science lessons. Students were 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. The items consisted of descriptions of activities believed to be commonly occurring in science lessons in Hong Kong secondary schools. Using this inventory, it is possible to compare the modes of instructional activities in science lessons, as perceived by the students, between EMI and CMI streams and among different ability strata of CMI schools.

Classroom Observation

In this part of the study, 10 Secondary 2 or 3 science lessons were randomly selected for classroom observation, five from the EMI schools and five from the CMI schools (Table 1), after obtaining consent from the principals of the schools and the teachers concerned.

The classroom observations were made in the second term of the 2000–2001 school year between March and June 2001. Bearing in mind that teaching styles are strongly affected by the ability and discipline of students, the low-ability CMI schools (i.e., CLOW stratum) were excluded

Table 1: The Contents and Features of the Ten Science Lessons Observed

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

from this exercise, as some students tended to show negative learning attitudes and behavior which could confound the interpretation of the classroom observation data in relation to the effects of MOI on instructional activities. Subsequently, 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 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.

The Science Lesson Evaluation Guide (SLEG) is the instrument used to audit and evaluate activities in science lessons. It 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 (Yip, 2001), being developed and validated by the science educators of the Department of Curriculum and Instruction, The Chinese University of Hong Kong. In the present study, however, the specific purpose of classroom observation is to compare the instructional activities taking place in science lessons of EMI and CMI schools. To achieve this purpose, classroom observation was focused on the teaching style and mode of interaction in science lessons. Eighteen items were selected and adapted from the TPEG to make up the SLEG focusing on three elements: (a) teaching style, (b) questioning skills, and (c) communication skills.

Each item in the SLEG is scored on a 5-point scale, ranging from 1 = rarely/weak to 5 = always/good. The observed lessons were evaluated using the SLEG by the first author and another science educator who is also experienced in training science teachers. Results were obtained by viewing the videotaped lessons as well as by direct observation in the classroom, which was mainly done by the first author. The two scores on each item from the two assessors were matched, and discrepancies in scoring were settled through discussion and negotiation between the assessors.

Results and Discussion

Students' Perceptions of Classroom Climate

Perceptions of classroom climate among different school strata

The analysis of students' perceptions among the four different school strata is summarized in Table 2.

Table 2: Analysis of Students' Perceptions of Instructional Activities in Science Lessons Among the Sampling School Strata

		Overall	EMI	CHIG	CMID	CLOW
Item 1: *Students listen to teachers' explanation*	*M*	3.29	3.40	3.33	3.21	3.23
	SD	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 2: *Teachers ask students questions*	*M*	3.15	3.17	3.16	3.10	3.16
	SD	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 3: *Students watch teachers' demonstration*	*M*	3.28	3.36	3.25	3.22	3.27
	SD	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 4: *Teachers manage classroom order*	*M*	3.17	3.16	3.19	3.13	3.20
	SD	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 5: *Students follow instruction of manual*	*M*	3.16	3.22	3.18	3.13	3.10
	SD	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 6: *Teachers check answers on work sheets*	*M*	3.21	3.25	3.24	3.19	3.15
	SD	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*

Table 2 (Cont'd)

		Overall	EMI	CHIG	CMID	CLOW
Item 7: *Students ask teachers questions*	*M*	2.82	2.80	2.78	2.80	2.93
	SD	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 8: *Students design procedures of experiment*	*M*	2.00	1.84	2.08	2.05	2.05
	SD	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 9: *Students conduct group discussion*	*M*	2.57	2.57	2.59	2.62	2.49
	SD	0.95	0.94	0.95	0.96	0.96
Difference of the mean	EMI		—	–0.02	–0.05*	0.08*
	CHIG		—	—	–0.02	0.10*
	CMID		—	—	—	0.13*

* Statistically significant

The mean score of EMI students on Item 1 (*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, EMI students perceived that more lesson time was spent on receiving instruction from the teacher than their CMI peers. This could imply that EMI students might be more attentive in lessons so that the teachers could focus more time on teaching. It may also relate to the fact that these students, being identified as abler, were academically more motivated. This implication is, however, not consistent with the responses to Item 4 (*Teachers manage classroom order.*), as there is no significant difference between the time spent by teachers in controlling class discipline as perceived by EMI and CHIG students. The mean score of CMID students on Item 4 is even lower than that of the EMI students, and the difference is statistically significant. This indicates that, according to the perception of EMI students, more time spent on listening to teachers' explanation does not necessarily imply more attentive behavior during lessons than their CMI peers. This argument can be substantiated by data obtained from classroom observations that will be discussed in a later section.

A different interpretation of the higher mean score of EMI students on Item 1 is that a more didactic, teacher-centered approach was adopted for science teaching in EMI schools. There is some support for this interpretation from the students' responses to Items 8 and 9, which were concerned with the prevalence of teacher-centered activities in science lessons. According to the mean scores on Item 9 (*Students conduct group discussion.*), the extent to which students are engaged in group discussion in EMI schools is less than that in CHIG and CMID schools. This observation suggests that EMI students were less likely to participate in interactive learning activities in science lessons.

EMI and CMI schools showed more substantial differences in the nature of practical work undertaken by the students as measured by Item 5 (*Students follow the instruction of manual to conduct experiments.*) and Item 8 (*Students design the experimental procedures by themselves.*). The mean score of EMI students on Item 5 is higher than those of CMI peers and the differences of the means are all statistically significant, indicating that EMI students perceived they followed the laboratory manual to a greater extent when performing practical work. Concomitantly, they had less chance to apply their scientific knowledge and use their own creativity to design investigations by themselves.

This interpretation is supported by the fact that the mean score of EMI students on Item 8 is particularly low, and is significantly lower than the mean scores of CHIG, CMID, and CLOW students. The much higher mean score of EMI students on Item 3 (*Students watch teachers' demonstration in the laboratory.*) also suggests that the practical activities undertaken by EMI students were more teacher-centered in nature, as they tended to spend more time watching teachers' demonstration in the laboratory than their CMI peers.

Implications

Two major implications can be drawn from the above analysis for the possible impact of MOI on instructional activities in science lessons. First, science instruction tends to follow a more didactic teaching approach in EMI schools, as their students perceived that they spent more time than their CMI peers listening to teachers' explanation, watching teachers' demonstrations, and following teachers' manuals when performing experiments. Moreover, EMI students believed they had fewer opportunities to engage in interactive learning activities such as group discussion, or in more creative practical work in which they could initiate or design their own investigations, as well as develop their language skills. Adopting a more teacher-centered approach to science teaching in EMI schools is understandable in view of the problems encountered by EMI students in learning science through a second language. Because of their limited English proficiency, EMI students might 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 during lessons. Instead, the teacher would favor 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 EMI schools, practical work tends to be conducted in a more traditional manner with the students following procedures prescribed in laboratory manuals. 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 EMI and CMI schools can also be attributed to the MOI used. Despite the higher abilities of EMI students, they may find it more difficult to engage in high-order thinking through a language in which they are less proficient. As a result, the practical work planned by their teachers is restricted to stereotypic experiments that make less demand on the use of communication skills and high-order cognitive skills.

Classroom Observation of Science Lessons

This part of the study is qualitative in nature, being complementary to the quantitative study on students' perceptions of classroom climate. Five EMI and five CMI science lessons were selected for classroom observation, which aimed at collecting first-hand information about instructional activities beyond perception-based data. With this method, a better understanding can be gained about 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 by Yip et al. (2003).

A summary of scores based on the 18 items of the SLEG is presented in Table 3. Because of the small number of science lessons observed and the potential for these lessons not to be representative of the different streams, no statistical analysis was carried out. Further, caution must be exercised when drawing conclusions 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.

Teaching style

In the traditional approach of science teaching, the teacher is mainly concerned with presenting established knowledge and algorithms to students. It is assumed that understanding scientific principles and their relationships will occur naturally after students have memorized a critical mass of facts (Lemberger, Hewson, & Park, 1999; Tobin & Gallagher, 1987). However, this approach does not necessarily 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, 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, Sheldon, & Dubay, 1990; Gunstone, 1995; Posner, Strike, Hewson, & Gertzog, 1982). From this perspective, meaningful learning in science requires interactive teaching styles that encourage students to express their views and ask questions, and promote a learning culture based on discussion and other student-centered activities.

Based on the data reported in Table 3, an overall review of the scores on the items on "Teaching style" indicates that both EMI and CMI teachers scored relatively high on Items 1, 2, and 4, but much lower on Items 5 and 6. This means that irrespective of the MOI used, the science teachers observed put great emphasis on explaining science concepts or delivering instruction to students (Item 1) and on establishing a good learning atmosphere in the class (Item 2), while the students were attentive and keen in science lessons (Item 4). These features are characteristic of a didactic approach in which the main task

Table 3: Item Scores of the SLEG for the Observed Science Lessons

	EMI schools						CMI schools					
	E-1	E-2	E-3	E-4	E-5	*M*	C-1	C-2	C-3	C-4	C-5	*M*
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 are 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 of a science teacher is to transmit scientific knowledge to students through lecturing (Gallagher, 1993; Lemberger et al., 1999; McRobbie & Tobin, 1995). This view is consistent with the students' general perception that they seldom asked questions on the lesson content, and very few interactive activities that promoted student participation were taking place in science lessons. The consequence of this mode of learning is reflected in students' performance in public examinations. It has been reported repeatedly that Certificate-level science students (Secondary 5 or Grade 11) in Hong Kong are good at recalling factual information but weak in applying their knowledge to novel situations or to solve realistic problems (Hong Kong Examinations Authority, 1999; Hong Kong Examinations and Assessment Authority, 2004).

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

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

For most of the lessons observed (e.g., 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 Lesson E-1, however, the teacher remained at the teacher's 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 sufficient 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. This teacher's inadequate verbal communication skills are revealed by the common occurrence of incoherent explanation and ambiguous questions in Lesson E-1 as depicted below, with the authors' comments added in italics:

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 were fragmentary and lacked logical coherence. They were not comprehensive to the class.)*

[T refers to a chart shown on the screen, pointing at the data for children and babies.]

T: Why is there such a great difference between these two groups of people? [There was initially no response from the students. After repeating the question for a number of times, T named a student.] *(The question was not clearly phrased. It referred to the difference in energy requirement between the child and the baby. The teacher did not try to rephrase the question or provide any prompts to improve students' response.)*

Although other EMI teachers observed were more fluent in the use of English, they shared some common features with the teacher of Lesson E-1. They tended to use short, disconnected statements which often failed to present abstract or complex ideas to the students accurately and comprehensively. As discussed in the later section on "Communication skills," this characteristic of sentence pattern used by 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.

With regard to the use of interactive teaching styles, EMI teachers were more concerned with ensuring that their students obtained correct answers or results for their worksheets or experiments than CMI teachers (Item 3). After completing practicals or worksheets, EMI teachers usually checked answers with the class without spending much time discussing with their students or assessing 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 is possibly due to student difficulties or lack of confidence in expressing ideas in English. CMI teachers, on the other hand, showed less frequency in checking correct answers with their students, and, instead, preferred 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 EMI teachers, CMI teachers tried more frequently 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 in both EMI and CMI schools tended to be teacher-centered and dominated by teacher talk. This reflects that teachers generally believed that learning involves the transmission of knowledge to students, rather than as a process of active construction of knowledge by students. However, the students in EMI science lessons were particularly reticent. They rarely asked questions related to the lesson content, or responded actively to teachers' questions. This is the case for all 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, EMI students responded much more passively than their CMI peers, a point that will be further elaborated in the next section 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.

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 MOI, however, seems to have some impact on the use of interactive activities in science lessons. There was no evidence of interactive activities in the five EMI lessons observed, but they 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 EMI students tended to complete their worksheets individually with little interaction among members of the same group. The teacher then usually checked the answers with the whole class to ensure that all students had correct answers for revision purposes. In 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.

Moreover, in the lessons observed, despite the fact that EMI students were allowed to communicate with each other in their mother tongue during group work, they were more inclined to work individually instead of in groups than CMI students. A possible reason is that EMI students needed more time to complete the worksheet in English. It would also be less time-consuming if the teacher checked the answers with the whole class instead of allowing the students to discuss among themselves and report their results in English. Furthermore, as many EMI students had difficulties in expressing their ideas fluently and effectively in English, they were reluctant to respond during class.

Questioning skills

Science teachers ask questions for a variety of reasons, such as 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, Englehart, Furst, Hill, & Krathwohl, 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 learning, a comparison of the practice of these skills in EMI and CMI science lessons will contribute to understanding the impact of MOI on science learning.

Asking recall-type questions occurred occasionally in both EMI and CMI classes (Item 7). These questions are of low cognitive demand, serving to refresh existing knowledge or to maintain students' attention. Besides asking recall-type questions, the questioning skills of EMI teachers were rather limited. While spending a lot of time "lecturing," EMI teachers 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 apply the knowledge learned in class for problem-solving or decision making (Item 9). Episode 1 (see Figure 1) taken from one of the EMI lessons illustrates this point.

Episode 1 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 has the following features:

- Most teacher questions were of low cognitive demand, requiring only one-word or simple answers from the students. Students usually reacted passively to their teachers' 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 EMI students were constrained by their limited communication skills in English to give elaborative answers. They might have acquired the concepts, but were unable to verbalize their understanding well.
- When the class responded passively or gave a wrong answer, the teacher seldom rephrased the question or used prompts to guide the students to apply their knowledge (Item 10). A possible explanation

Figure 1: Episode 1 Extracted 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*(-old)* 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.]

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 stands for "Student"; notes/comments added in by the authors are in italics.

for the lack of probing questions by 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. In addition to the use of simple questions and short sentences for classroom communication, EMI teachers need a repertoire of strategies to guide their students to understand the questions asked and articulate 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 incomplete or inaccurate answers from their students. Again, this may be related to the inadequate

English proficiency of the students, who experienced difficulties in expressing abstract and complex ideas accurately by words. This problem was quite obvious in the observed lessons. In order to save time and ensure smooth flow of the lesson, teachers found it more efficient to give the correct answers directly, instead of guiding their students to express their ideas in English.

CMI teachers, on the other hand, asked more questions that assess students' understanding or higher cognitive skills (Items 8 and 9) in the science lessons. Episodes 2 and 3 from Lessons C-2 and C-5 (see Figures 2 and 3) illustrate the type of interaction related to the use of questioning skills in the CMI classrooms.

Figure 2: Episode 2 Extracted 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.

Key: T stands for "Teacher"; S stands for "Student" with S1 for "Student 1" and S2 for "Student 2" and so on.

Figure 3: Episode 3 Extracted 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, and 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. T guides the class to draw a conclusion from their results.]

T: [T projects a ray diagram of the eye on the screen.] 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 questions related to the design of their method.]

Key: T stands for "Teacher"; S stands for "Student."

The episodes taken from CMI science lessons illustrate that, in comparison with EMI students, CMI students were more active in responding to teacher questions, and were 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., 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 pre-existing 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 EMI lessons.

The development of a more proactive classroom atmosphere in 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 the students relate their everyday life experience to the pH context by alerting them to the relationship between their previous knowledge of hydrogencarbonate indicator and the concept of acid and alkali. Similarly, the teacher in Lesson C-5 guided her students to verbalize 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 MOI, were of low cognitive demand, the questions asked by CMI teachers were more specific and clearly expressed than those of EMI teachers. As a result, CMI students were able to 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 posed by CMI teachers were usually more coherently organized so that the students could be led step by step to build up new concepts from existing knowledge.

Communication skills

The teachers in all the observed lessons generally demonstrated adequate communication skills (Item 13). Compared with CMI teachers, EMI teachers tended to use relatively short, simple sentences for communication in class. This is understandable in view of the restricted linguistic proficiency of 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. Using inaccurate, fragmentary phrases and sentences, the teacher was unable to communicate scientific ideas effectively in the lesson. The students seemed 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 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 (see Figure 4).

In Episode 4, the teacher attempted to prompt the students to construct the concept of heat transfer through questioning. However, the students were unable to distinguish between temperature and heat content, probably due to the close relationship between the two concepts. The use of short, disconnected questions did not facilitate the students to construct 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

Figure 4: Episode 4 Extracted From Lesson E-3 (Heat Transfer)

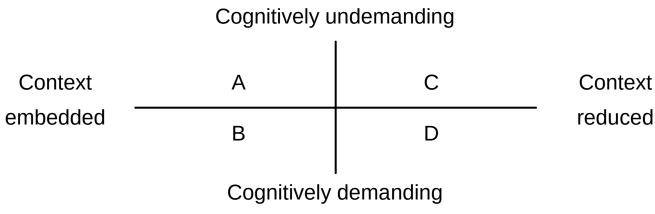
T:	What is heat? [No response from the class.] Heat is energy.
T:	[T shows two glasses of water.] How to tell which glass of water has more heat?
S1:	Use a thermometer.
T:	To measure what?
S2:	Temperature. *(Note that T has not guided the students to develop a correct concept about the heat content in 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 80ºC is left at room temperature, what will happen?
S:	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.

Key: T stands for “Teacher”; S stands for “Student” with S1 for “Student 1” and S2 for “Student 2” and so on; notes/comments added in by the authors are in italics.

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, showed that the students were unable to follow the teacher's line of thinking and failed to develop an understanding of the principle of heat transfer. In fact, the deduction made by the teacher that a temperature gradient was a necessary condition for heat flow could not be arrived at from the given example.

These 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, pp. 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 (see Figure 5).

Figure 5: 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 to 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 (1998) identified in her research on science learning of second-language learners. 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 decontextualized language, and the students shifted toward less context-embedded ways of expression. The final stage of student journal writing, which corresponds to Quadrant D, provides some evidence of second-language growth in that students included in their journal wordings and phrases that the teacher used during the guided reporting session.

Based on Cummins's (2000) 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.

CMI teachers were on the whole proficient with using Chinese for classroom instruction (Item 13). Although the science lessons for Secondary 2 and 3 students were mainly concerned with simple, low-level scientific knowledge, the quality of explanation provided by CMI teachers was usually good (Item 14), as illustrated by Episodes 2 and 3. In Episode 2, by refreshing the students' knowledge on the color 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 verbalize 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.

In terms of the final four items of the SLEG, the students in the ten science lessons observed were generally attentive and keen to learn. Mobility in the classroom was appropriate (Item 15), although EMI teachers were slightly less mobile than 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 EMI and CMI teachers should not be attributed to the MOI, 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 his tendency to face the screen instead of the class when referring to the information displayed.

All teachers observed were energetic and enthusiastic, irrespective of the MOI used (Item 17). CMI students appeared to demonstrate greater interaction among themselves during discussion or practical work than 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 the previous section "Teaching style," it has been noted that during the lesson, EMI students were more concerned with completing their own worksheet than participating in group discussion. A possible reason suggested is that EMI teachers, mindful of their students' restricted English proficiency, 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 and Implications

Since the curriculum reforms of the U.K. and the U.S. in the 1960s, fostering conceptual understanding of scientific knowledge rather than its memorization has become a major aim of the science curriculum. 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, Parker, & Nugent, 1997). This teacher-centered mode of instruction is also found to dominate the science classrooms of the present study, irrespective of the MOI used.

The findings based on the survey of students' perception in this study, however, reveal that there are substantial differences between the teaching styles of EMI and CMI teachers. Compared with CMI teachers, EMI teachers were more focused on exposition of subject content and transmission of established scientific knowledge. Concomitantly, 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 results obtained from 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 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 CMI lessons, 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 EMI lessons. EMI students were on the whole much more passive than CMI students in responding to teachers' questions or raising questions on the lesson content.

The more passive role of EMI students in the classroom or laboratory can be partially attributed to the problems of learning science in a second language. As EMI students are limited by their low levels of English proficiency, there is a significant gap between how they conceptualize in English and how they conceptualize in their own native language, and between what they can understand in English and what they can articulate in English (Teemant, Bernhardt, Rodriguez-Munoz, & Aiello, 1995). To bridge such gaps, it may be necessary to make special provisions for these students in learning science. On the 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 program (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 MOI. In 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. CMI teachers, on the other hand, asked more high-order questions, and their students were more active in responding to teacher questions. The difference in the difficulty level of teacher questions between 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 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, EMI students were passive in answering even recall-type questions, and they rarely gave elaborative answers. The consequence of the lack of class interaction is that the teachers tend to dominate the talk in class, ask mainly recall-type questions, and most often answer their own questions. In contrast, CMI classrooms were more interactive, with the students playing a more active role in answering and asking questions. 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, EMI teachers had to use more simple sentences or phrases for instruction than 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 domination of EMI lessons by teacher talk also deprived students of the opportunities to develop and acquire literacy skills through the meaningful and purposeful use of English in discourses within scientific contexts, which is the main goal of using English as the MOI for science.

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 programs 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 EMI and CMI schools in the nature and quality of instructional activities in science lessons suggest that 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 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 conceptualize 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 EMI students must learn science and other content subjects through a complete immersion in English, without using the first language in a supportive role. With reference to Cummins's (2000) framework of linguistic and cognitive demands of academic tasks, there is a need for teacher educators to provide programs that help science teachers develop the skills for teaching cognitively demanding concepts in simple English, and for guiding their students to move toward less context-embedded communication as they show advancement in linguistic and cognitive abilities. In reviewing the implementation of MOI policy in Hong Kong, it is also opportune to consider how the learning of science and language literacy skills may complement and strengthen each other:

> Science strengthens literacy skills by infusing them with meaning and purpose. Setting language in an engaging context such as science inspires students to reach for the tools of language in order to uncover and internalize the secrets about the world that science can reveal to them. Literacy skills strengthen science learning by giving students the lens of language through which to focus and clarify their ideas, conclusions, inferences, and procedures. By integrating those groups of skills, teachers can improve students' abilities and raise achievement levels in both areas at once, and do so more effectively and efficiently than if the two skill areas are taught separately. (Thier, 2002, p. 6)

The synergies between science learning and the acquisition of language skills are essential for the development of scientific literacy, but are often neglected by science teachers. There are a number of strategies that facilitate students to acquire science knowledge while building their language skills (Sheffield City Polytechnic, 1992; Thier, 2002). The mastery of these strategies should be an important pedagogical skill for all science teachers, irrespective whether they are using Chinese or English as the MOI.

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