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Scientific Literacy of Hong Kong Students and Instructional Activities in Science Classrooms

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In this study, instructional activities in science classrooms are examined in order to collect evidence to account for the strengths and weaknesses of Hong Kong students in scientific literacy as reported in the PISA 2000 project. The study consists of a questionnaire survey on the perceptions of classroom climate of science lessons of 17,616 Secondary 2 (S2) students and classroom observations of seven science lessons. According to students' perceptions, science lessons were generally didactic; interactions were satisfactory but student questions and group discussions were less frequent. Class practicals were mainly demonstrations and pre-assigned investigations with detailed instruction. Classroom observations basically substantiate the findings obtained from the student survey that science lessons were didactic in nature and teacher-student interactions were mainly confined to low-order teacher questions. These problems were particularly serious when English was used as the medium of instruction. The prevalent use of highly prescriptive manuals and worksheets for practicals tended to discourage students from developing a genuine understanding of the nature and processes of scientific inquiry. These observations provide some preliminary evidence to account for the PISA finding that Hong Kong students were less successful on items that assess "recognizing questions" and "drawing conclusions."

Introduction

In the scientific literacy framework of PISA 2000, the performance of Hong Kong students lies at the top third position among the 41 participating countries/regions, being comparable to that of the students of Korea and Japan (Organisation for Economic Co-operation and Development, 2003). With regard to the five components of scientific literacy, Hong Kong students perform well on items that assess the ability to "use and understand scientific concepts" (62.9%) and "identify evidence" (60.8%), satisfactorily on items that assess the ability to "draw conclusions" (49.6%), but less satisfactorily on items that assess the ability to "recognize questions" (43.7%) and "communicate conclusions" (33.2%) (Yip & Ho, 2003/2004).

These findings inform us about the strengths and weaknesses of Hong Kong students in scientific literacy. To understand the differential achievement of Hong Kong students in the various components of scientific literacy, reference should be made on how science is taught inside the classroom — that is, the implemented science curriculum in schools. The Hong Kong science curriculum for Secondary 1–3 (S1–S3) advocates an investigative approach of science teaching. This approach emphasizes the use of practical work to provide the learning experiences that enhance the acquisition of knowledge and skills. In science lessons, students should be actively engaged in defining problems, designing experiments to find solutions, carrying out practical work, and interpreting the results (Curriculum Development Council, 1998). The successful implementation of such a science curriculum, particularly with regard to the investigative approach, depends very much on the teaching approach of the teachers. This article examines the instructional activities occurring in science lessons at the junior secondary level in Hong Kong by analyzing students' perceptions and conducting classroom observations. This analysis will help us understand the types of classroom interactions that may occur in science classrooms and whether they are conducive to the development of various abilities that contribute to the development of scientific literacy. It is hoped that the results can provide evidence to account for the strengths and weaknesses of Hong Kong students in scientific literacy as reported in the PISA 2000 study.

Method of the Study

The results reported in this article are mainly based on the data obtained from a large-scale study of the effects of the medium of instruction (MOI) on students' achievement in science (Tsang, 2002), but with a focus on the nature of instructional activities occurring in science lessons. The information on the instructional activities was collected from two sources: students' responses to a questionnaire, and observation of science lessons. The questionnaire was completed by a cohort of S2 (equivalent to Grade 8) students from 100 secondary schools which were sampled by the stratified random sampling method: 25 schools were randomly selected from EMI (English as the medium of instruction) schools, as well as high-ability, medium-ability and low-ability CMI (Chinese as the medium of instruction) schools respectively. The CMI schools were stratified into three ability groups according to the mean AAI (Academic Aptitude Index) scores of their S1 student intake. Although this student sample is different from that involved in the PISA 2000 study, which were a random sample of 15-year-old students from secondary schools, it is a representative sample of junior secondary students of Hong Kong. Their experiences of instructional activities in science lessons can be related to the development of scientific literacy as identified at a later stage. The classroom observation of science lessons was conducted in seven schools.

Students' Perceptions of Classroom Climate

In April to June of 2001, 17,616 S2 students 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: 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 (please refer to Table 2). This inventory helps to understand the modes of instructional activities in science lessons, as perceived by the students studying in both the EMI and CMI schools.

Classroom Observation

Seven science lessons that included both teaching and practical activities were randomly selected for classroom observation between January and June of 2001. Three of these lessons used EMI and the other four used CMI (Table 1). All lessons observed were single periods conducted in the science laboratory, ranging from 35 to 40 minutes. With the consent of the teachers, these lessons were also videotaped.

Table 1. The Contents and Features of the Seven Science Lessons Observed

Lesson	School	MOI	Grade	Topic of lesson	Activities
E-1	TH	EMI	S2	Neutralization	• Lecture on acids and alkalis and instruction on neutralization practical + group experiment + checking answers with class
E-2	LTP		S3	Electrolysis	• Instruction and demonstration on setting up experiment on electrolysis + practical + checking answers with class
E-3	LP		S3	Food tests	• Instruction on food tests + group experiment + discussion of results with class
C-1	SY	CMI	S1	States of matter	• Introduction to the three states of matter + group experiment
C-2	YY		S2	pH indicators	• Lecture on detergents as acids and alkalis, and pH indicators + group experiment on pH indicators
C-3	CA		S3	Lens	• Lecture on properties of convex lens + instruction on practical + group experiment on convex lens
C-4	TKP		S2	Resistance	• Lecture on meaning of resistance + investigations on factors affecting resistance of a wire

For the present study, the specific purpose of classroom observation is to review the instructional activities taking place in science lessons. To achieve this purpose, classroom observation in the present study will only focus on the teaching style and mode of interaction in science lessons. These were assessed by the authors using a 10-item instrument called the Science Lesson Evaluation Guide, which is 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.

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/instruction*"), 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 of the lesson time.

Results and Discussion

Students' Perceptions of Classroom Climate

Students' perceptions of classroom climate in science lessons are summarized in Table 2.

Table 2. **Students' Perceptions of Instructional Activities in Science Lessons**

	Mean score	*SD*
Item 1: *Students listen to teachers' explanation*	3.29	0.78
Item 2: *Teachers manage classroom order*	3.17	0.77
Item 3: *Teachers ask students questions*	3.15	0.77
Item 4: *Students ask teachers questions*	2.82	0.80
Item 5: *Students conduct group discussion*	2.57	0.95
Item 6: *Students watch teachers' demonstration*	3.28	0.71
Item 7: *Students follow instruction of manual*	3.16	0.85
Item 8: *Students design procedure of experiment*	2.00	0.91
Item 9: *Teachers check answers on work sheets*	3.21	0.80

Score: 1 = never happen; 2 = rarely happen; 3 = sometimes happen;
4 = always happen.

Items 1 and 2 are concerned with the teaching style of the teachers. The relatively high score (> 3) of these two items suggests that science lessons are perceived by the students as basically didactic in nature, as the teachers provided explanations for most of the lesson time and were concerned with maintaining good class discipline. Interactions are satisfactory as the teachers asked questions occasionally (Item 3), and students sometimes asked questions (Item 4). Meanwhile, group discussion (Item 5) occurred less frequently (mean score = 2.57).

Items 6–9 are related to the conduct of practical work. According to students' perceptions, teacher demonstration (Item 6) remains to be an important form of practical activity in science lessons. This type of activity may help to clarify science concepts and provide students with a feel of the scientific phenomena concerned (Duggan & Gott, 1995). However, they may not be able to facilitate the development of scientific thinking and investigative skills.

For class practicals, students are often provided with full instruction on the procedure (Item 7), and they are seldom allowed to design the methods of investigation by themselves (Item 8). This indicates that some form of "guided discovery" is practiced in the science lessons during which students are guided through prescribed procedures to obtain predetermined results. To ensure that all students secure the expected learning outcomes, teachers are prone to checking "model" answers with the class after the students have completed the practical worksheet (Item 9). This is a common learning experience of Hong Kong students in the study of junior science.

Observation of Science Lessons

Analysis of Observed Lessons

Classroom observation in this study aims at collecting first-hand information about instructional activities beyond perception-based data. This method may provide a more comprehensive picture of the interactions and activities taking place in the science classrooms. However, caution must be exercised when interpreting these observations, as the lessons selected may not be representative of the school strata under study, and the classroom climate may be strongly

Table 3. Item Scores of the Science Lesson Evaluation Guide for the Observed Lessons

		E-1	E-2	E-3	Mean EMI score	C-1	C-2	C-3	C-4	Mean CMI score	Mean score
1.	Pupils listen to teacher's explanation/instruction	5	4	4	4.33	4	3	3	4	3.50	3.86
2.	Pupils ask questions on lesson content	1	1	1	1.00	2	3	2	2	2.25	1.71
3.	Use of interactive activities	1	1	1	1.00	1	1	2	1	1.25	1.14
4.	Teacher asks questions on recall	3	2	3	2.67	3	3	2	3	2.75	2.71
5.	Teacher asks questions to assess understanding	1	1	1	1.00	3	5	2	4	3.50	2.43
6.	Teacher asks high-order questions	1	1	2	1.33	2	3	2	3	2.50	2.00
7.	Pupils give long, thoughtful responses to questions	1	1	1	1.00	2	2	2	3	2.25	1.71
8.	Pupils respond actively to questions	1	1	1	1.00	3	3	3	3	3.00	2.14
9.	Interaction among pupils during practical	3	4	3	3.33	4	4	4	3	3.75	3.57
10.	Teacher checks answers on worksheet with pupils	–	4	4	4.00	4	2	3	3	3.00	3.33

Score: 1 = rarely/weak; 3 = occasionally/satisfactory; 5 = always/good.

affected by a variety of uncontrollable 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.

Table 3 provides a summary of the scores of the observed lessons on the 10 items of the Science Lesson Evaluation Guide.

According to the results reported in Table 3, the observed lessons score relatively high on Item 1, but much lower on Items 2 and 3. This statement is generally valid for the lessons observed despite the slight differences in scores between the EMI and CMI schools. This indicates that the science teachers tended to put great emphasis on explaining science concepts or delivering instruction to students (Item 1). This observation is consistent with the students' perceptions of classroom climate as reported in the previous section.

The students, on the other hand, seldom asked questions (Item 2), and interactive activities were rarely observed (Item 3). These features are characteristic of a didactic lesson in which the main task of the teacher is to transmit 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, Hewson, & Park, 1999; McRobbie & Tobin, 1995). Questions were used by teachers as a means to promote student interaction, but most of them were low-order questions that could be answered by recall (Item 4). High-order questions, including those that assess student understanding, were less frequently asked (Items 5 and 6). These questions were particularly rare in the EMI classrooms, probably because such kind of questions makes a high demand on English proficiency that may still be lacking in most of the EMI students in this study.

As most of the questions asked by teachers were of low cognitive demand, they failed to stimulate the students to answer actively or give thoughtful responses (Items 7 and 8), although the CMI students responded more actively to teachers' questions than their EMI counterparts. The low extent of student participation, as measured by the frequency of student questions (Item 2) and the use of interactive activities (Item 3), reveals that the science lessons observed are rather teacher-centered for both EMI and CMI schools and are dominated by teacher talking. 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, nor responded actively to teachers' questions. In most EMI 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.

Most students seemed to enjoyed the practical activities and they interacted actively with each other during practical (Item 9). After the class had completed their reports, teachers usually checked answers with the class without spending much time discussing with their students or assessing their students' understanding (Item 10). 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 reluctant to voice their views. Again, this was possibly due to their incapability or lack of confidence to express their ideas in English. Some of the CMI teachers, however, were concerned with checking answers on the worksheet or the results of an experiment. They attempted to elicit students' responses by asking individual students or groups instead of giving out the answers directly.

Conduction of Class Practical in Science Lessons

In addition to a general review of the instructional activities that take place in science lessons as assessed by the Science Lesson Evaluation Guide, a more in-depth understanding of the learning experiences gained by the students can be obtained by examining how class practical is actually conducted in science lessons. An investigative approach is emphasized in the junior science curriculum of Hong Kong and students are expected to acquire science concepts and investigative skills through participation in practical activities. However, it is doubtful whether such objectives can be achieved by the students. In general, students have to follow highly prescriptive instruction and report their results by completing worksheets. Episodes 1 and 2 which are extracted from the observed lessons illustrate the nature of practical activities participated by students and the learning outcomes that can be achieved.

The episodes provide an example of the type of investigative activities commonly carried out by students at the junior science level. These episodes show that in general a "guided-discovery" approach is advocated. By following highly prescriptive procedures and answering closed questions in the worksheet, students are guided to arrive at predetermined conclusions and to rediscover established scientific knowledge. Such practical exercises do not provide the opportunities for students to plan and design their own investigations, to report and interpret the results in their own words, and to draw conclusions by critically analyzing their results (Yip & Ho, 2003/2004; Yip & Yung, 1999). They will facilitate the acquisition of observation power and manipulative skills, but are not conducive to the development of other skills that are valued by the curriculum, such as the abilities to identify investigative problems, to formulate hypotheses, to design methods of investigation, or to recognize and evaluate evidence. In most practical sessions, our students may be actively engaged with hands-on physical activities, but they are not provided with the mental challenges that facilitate the development of processing and investigative skills, and the ability to communicate explanations and conclusions in science.

Episode 1 (from Lesson C-1: States of matter)

The students worked in groups of 4–5. After each group had classified a number of materials into solid, liquid and gas, the students were asked to perform an experiment by following the instruction in their workbook as follows:

> *Put a wooden cylinder into a plastic syringe. Put the plunger back into the syringe and try to compress the wooden cylinder.*
> 1. *Can the shape of the wooden cylinder be changed easily?*
> 2. *Does the wooden cylinder take up space?*
> 3. *Does its volume change when it is being compressed?*

The same procedure was repeated for water and air. At the end of the practical, the students were asked to complete a table that summarizes the properties of solid, liquid and gas under the following headings: Does it take up space? Can the shape be changed easily? Does its volume change when it is compressed?

Episode 2 (from Lesson C4: Resistance)

The teacher demonstrated how to control the loudness of a radio and the brightness of a lamp by turning the control knobs. The teacher then introduced the concept of resistance. Students were asked to carry out a series of investigations that study the factors affecting the resistance of a wire by following the instruction in their workbook as follows:

> 1. *Set up a circuit with a thin nichrome wire as shown in a diagram. Close the switch and note the brightness of the bulb.*
> 2. *Now replace the thin nichrome wire with a piece of thick nichrome wire. Close the switch and note the brightness of the bulb again.*
> 3. *Does the resistance of a wire depend on its thickness? The electric current is larger when a _____ wire is used.*

This was followed by a similar experiment that studied the effect of the length of a wire on its resistance.

Conclusions

Based on students' perceptions and our direct observation of science lessons, the present study shows that the science lessons at the junior secondary level are generally dominated by a didactic, teacher-centered mode of instruction. This approach is consistent with the belief commonly held by many science teachers that their primary role is to identify the major concepts in science and present them in an intelligible way to students (Lemberger, Hewson, & Park, 1999; Yerrick, Parke, & Nugent, 1997). With an emphasis on practical work and the common use of guided laboratory worksheet, our students have ample experiences in making observations and evaluating evidence.

The above mode of instruction in the science classroom may account for the PISA result that Hong Kong students performed relatively well in items that are concerned with "the use and understanding of scientific knowledge" and "identifying evidence."

The provision of highly prescriptive procedures and worksheets in class practicals ensures that students are able to perform investigations successfully and obtain the desired results. However, students will fail to develop the skills for identifying investigable problems, designing experimental methods, and drawing conclusions with reference to available evidence. All these are essential elements for understanding the process of scientific inquiry and developing the skills for problem solving. These weaknesses of the local implemented science curriculum may provide some preliminary evidence to account for the less satisfactory performance of Hong Kong students on the PISA items that assess the skills for "recognizing questions" and "drawing conclusions."

The prevalence of closed questions in the practical worksheet may help the students make observations, interpret results, and draw conclusions. However, this practice does not provide the learning experiences for students to express their reasoning and conclusions verbally, which is important for the development of communication skills. The highly prescriptive practical worksheet can be improved by including some generic questions that guide the students to design their own investigations and to discuss and interpret their observations in their own words (Yip & Yung, 1999).

In all the observed lessons, there are no activities that aim at developing students' reading skills and comprehension power through reading extensive passages. This may account for the poor performance of Hong Kong students on certain PISA items which make a great demand on reading and comprehension skills, such as the *Semmelweis' Diary* item that asks students to draw conclusions on the cause of puerperal fever and the *Ozone* item that asks students to explain the formation of ozone (Yip, 2004/2005). This deficiency can be made up by employing active reading activities (Centre for Science Education, 1992), such as text completion, sequencing, text marking, devising questions and using teacher-generated questions. The application of these interactive learning methods will facilitate student comprehension, and the development of reading skills and communication skills, which are essential for expanding the self-learning repertoire of the students.

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