Science laboratory learning environments in junior secondary schools

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Contents

Abstract

A Chinese version of the Science Laboratory Environment Inventory (SLEI) was used to study the students' perceptions of the actual and preferred laboratory learning environments in Hong Kong junior secondary science lessons. Valid responses of the SLEI from 1932 students of grade 7 to grade 9 indicated that an open-ended inquiry approach seldom takes place in the laboratories. Students had a strong preference for an environment which emphasizes an open-ended investigative approach in learning

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science. Interviews with teachers also found that teachers were willing to provide a learning environment for investigative approach, yet little or no action was taken in this respect. Factors identified for not implementing the inquiry approach include concerns about discipline problems, safety, large class size, laboratory support, management, and examination-oriented culture. There is no straightforward resolution to these concerns. It involves an increase in the amount of teaching resources, a change in management practice as well as a transformation of culture in the society. This study showed that the SLEI instrument did prove to be useful to diagnose the areas for improvement in the laboratory learning environments but some items of the instrument may need to be re-phrased to suit the development and learning experience of students in junior secondary level.

Keywords: Learning environment; Laboratory; Science; Junior Secondary Schools; Inquiry learning.

Introduction

Learning in the laboratory has long been regarded as an important component in science education. Laboratory activities provide students with first-hand experience in seeing how nature works. Laboratory is specially designed and equipped for science experiments, demonstrations and investigations in a safe environment. In a review article Hofstein and Lunetta (1982) reflected that despite of the common perception laboratory activities help students in learning science, researches had not revealed, with clear relationships, that learning in the laboratory was effective to develop students' conceptual understanding and scientific thinking skills as well as to foster a positive attitude towards science. Laboratory should not only be a place to demonstrate the phenomena described in the textbooks and to verify principles and laws, but it should also be a place where students are given the opportunities to go through the processes of scientific inquiry on their own. Twenty years later, Hofstein and Lunetta (2003) did a similar review again. During that twenty-year period, reforms in science education had changed the content and the pedagogy of science learning and teaching.. The shift of emphasis towards learning science through inquiry took place in many places around the world (Abd-El-Khalick, et al, 2004). New research instruments and methodologies were also developed. At present, researchers are better equipped to study factors that affect learning in the laboratory.

The Hong Kong Junior Secondary Science Curriculum (JSSC) (CDC, 1998) has been implemented since 2000. The curriculum advocates that "the investigative

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approach, which involves students in defining problems, designing experiments to find solutions, carrying out practical work and interpreting the results, should be employed" (CDC, 1998, p.2). This curriculum emphasizes the use of experimental work for inquiry learning approach. Learning in laboratory may play an increasingly important role in promoting the paradigm shift in science learning, providing that the learning activities are designed with inquiry approach in mind, and students are given adequate opportunities to construct the concepts through metacognitive processes and interactions with their peers and teachers. To achieve meaningful learning outcomes in the laboratory, the learning environment should favour these processes to occur. However, the curriculum developed by the central curriculum agency may not be implemented in fidelity at the classroom level. From a number of case studies, Anderson (1996, 2002) had summarised the barriers and dilemma, for which teachers encountered in implementing new approaches in science teaching, into three dimensions, namely the technical dimension, the political dimension, and the cultural dimension. Thus a study of the laboratory learning environments may provide us a channel to understand to what extent the inquiry learning has been practiced in reality as well as the barriers and dilemma faced by the teachers.

The importance of learning environment on the effectiveness of learning has drawn the attention of many researchers. It was found that a close match between the students' perceptions of the actual and preferred learning environments was likely to have positive effect on the attitudinal and cognitive learning outcomes (Fraser 1994, 1999). Instruments used to study different settings of learning environment have been developed in the past 30 years (Fraser 1998a, 1998b). In particular, Fraser, McRobbie, and Giddings (1993) had developed and validated the Science Laboratory Environment Inventory (SLEI) to study the perceptions of students on laboratory learning environments. Such instrument was adapted in this study to explore the students' perceptions of science laboratory learning environments in Hong Kong junior secondary schools. The results would be used to identify problems in the laboratory learning environments. Suggestions for improvements in the existing learning environments would be made and ultimately it is hoped that better learning outcomes can be achieved. Specifically, the main objectives of this study were:

(1) to find out the actual and preferred laboratory learning environments perceived by junior secondary students in Hong Kong;

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(2) to compare the differences, if any, between the actual and preferred laboratory learning environments perceived by students.

The adaptation of the SLEI to junior secondary levels in this study is by no means trivial as it was first developed and validated at the senior secondary level (Fraser, McRobbie & Giddings, 1993). Thus the validation of the SLEI in this context was a prudent process which is worthy of attention for future studies.

The instrument

Statement of the problem

The Science Laboratory Environment Inventory (SLEI), an instrument developed specifically to assess the environments of science laboratory classes, was adopted in this study. SLEI was first developed in Australia (Fraser, McRobbie & Giddings, 1993) and it was field-tested and validated in six countries namely the US, Canada, England, Israel, Nigeria, and Australia with a sample of over 5447 students in 269 classes (Fisher, Henderson & Fraser, 1997; Fraser & McRobbie, 1995). The instrument was also adapted in Singapore to study 1592 grade 10 chemistry students (Wong & Fraser, 1996) and cross-validated in Brunei Draussalem with 644 grade 10 chemistry students (Riah & Fraser, 1998). In Korea, the English version was translated into Korean and the questionnaire was administrated to 439 high school students from three streams, viz. humanities stream, science-oriented stream and science-independent stream (Lee & Fraser, 2002). Validity was established and similar patterns in the Western countries were replicated in these studies.

In developing the SLEI, Fraser, McRobbie and Giddings (1993) identified five dimensions which were considered important in the unique environments of the science laboratory class. These dimensions are (1) teacher attitudes and behaviour, (2) content and nature of laboratory activities, (3) instructional goals, (4) social variables, and (5) management such as availability of space and materials (Hofstein and Lunetta, 1982). All these dimensions of science learning in laboratories are generic and common at both senior and junior secondary levels. In Hong Kong, the science learning environments in junior and senior secondary classes are similar. Such similarity can be observed from the physical set-up of the laboratories, which are built with the same design and are under the same management such as staffing and equipment pool. The other similarity is that the central curriculum development

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agency, the Curriculum Development Council, advocates the same pedagogical approaches to teaching and learning science at both junior and senior secondary levels in Hong Kong (CDC 1998; CDC 2002a; CDC 2002b; CDC2002c). Students will develop scientific knowledge and science process skills, namely, observing, classifying, measuring, and experimenting skills through inquiry process. In view of the above, the SLEI instrument is likely to be applicable in junior science classes in Hong Kong although it was originally developed and validated for senior secondary science classes elsewhere. In Taiwan, Tsai (2003) has already extended the use of SLEI in junior secondary science classes. The instrument has proved to be rather robust to its wide range of applicability to different academic levels, different science disciplines as well as various school systems in different countries.

The SLEI questionnaire consists of five scales namely Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment (Fraser, McRobbie & Giddings, 1993). Each scale is measured by seven items. For each item, a five-point scale is used to describe how often the item happens in the laboratory classes, ranging from (1) “Almost Never”, (2) “Seldom”, (3) “Sometimes”, (4) “Often”, to (5) “Very Often”. In this study, a Chinese version of the SLEI was adapted for use in junior secondary science classes. There were two forms of the questionnaire, one described the students’ perceptions of the actual laboratory environment; the other one was the students’ perceptions of the preferred environment. The full set of the questionnaire can be found in Fraser, McRobbie, & Giddings (1993) to which the item numbers are referred hereafter in this paper. The descriptions and sample items of each scale are listed in Table 1.

Table 1. Scale description and sample items of the SLEI

Scale	**Description**	**Sample item**
Student Cohesiveness	The extent to which students know, help, and are supportive of, one another.	Members of this laboratory class would help one another. (preferred) (+)
Open-Endedness	The extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation.	In our laboratory sessions, different students collect different data for the same problem. (actual) (+)
Integration	The extent to which the laboratory activities are integrated with non-laboratory and theory classes.	The topics covered regular science class work would be quite different from topics dealt with in laboratory sessions. (preferred) (−)

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Rule Clarity	The extent to which behavior in the laboratory is guided by formal rules.	There are few fixed rules for students to follow in laboratory sessions. (actual) (−)
Material Environment	The extent to which the laboratory equipment and materials are adequate.	The laboratory is an attractive place in which to work. (actual) (+)

(+) Items are positively worded.

(−) Items are negatively worded and are scored in reverse manner.

In adapting the SLEI to local junior secondary science classes, it was translated into Chinese. The translated version was reviewed by two secondary science teachers. Four students were invited for an interview to go through every item in the questionnaire. Modifications in the wording were made to preserve the original meaning in the original English version and to fit into the common usage in the local context. Five reversed-worded items (items 3,5,15, 20, 25) read awkward in translated version were changed back to positive-worded items, reducing the total number of reversed-worded items from 13 to 8.

The Main Study

The data Set

The final Chinese version of the 35-item SLEI was administrated to 2061 students studying the Hong Kong Junior Secondary Science Curriculum in Grades 7, 8, and 9 with percentages being 6, 63, and 31 respectively. In fact, it is very common that a teacher teaches the same science subject at all three grade levels, and students of all these three grade levels share the same laboratory and use the same textbook series. In terms of the laboratory learning environments, the three grade levels are indeed very similar. In the sample of the study, male and female students were in the ratio of 1: 0.82. It included both high and low academic achievers. Some students use English as a medium of instruction while others use Chinese as a medium of instruction. This sample represented a typical profile of the student population in Hong Kong. After a preliminary screening to filter out invalid questionnaires, the number of valid responses was 1932. This formed the data set for analysis in the main study.

To help us interpret the data, teachers of the participating schools were invited for interviews. Finally two teachers were interviewed over the telephone and four

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teachers attended a group interview. The interview questions were asked with reference to the 35 items of the SLEI questionnaire. Teachers were asked to describe the actual and preferred laboratory practices and to elaborate on their views. The interviews lasted for about one hour.

Data analysis and results

Reliability and factor structure

The data set of the student was checked for reliability. The Cronbach alpha coefficients were listed in Table 2.

Table 2. The reliability coefficients of the of SLEI scales

	No. of	Alpha Reliability	
Scale	**Items**	**Actual**	**Preferred**
Student Cohesiveness	7	0.71	0.72
Open-Endedness	7	0.55	0.62
Integration	7	0.64	0.52
Rule Clarity	7	0.54	0.47
Material Environment	7	0.73	0.81

The reliability coefficients of Student Cohesiveness and Material Environment scales were greater than 0.7 indicating that these two scales were generally reliable. However the reliability coefficients of the other three scales ranged from 0.47 to 0.64 suggesting that items in these three scales were inconsistent. An examination of the item-total correlations was done to identify items with which the correlations with their own scales were low (Table 3). Many of these items were the reversed-worded items. Barnette (1999) found that a scale with reversed-worded items mixed with positively worded items could have strong effects on Cronbach's alpha coefficients. When mixed-worded items of a unidimensional scale were subjected to exploratory factor analysis, separate factors associated with positively and negatively worded items were often found (Marsh, 1996; Barnette, 2000; Brown, 2003). This effect, which also happened in other social science research, appeared to be more pronounced in cross-cultural studies (Eastman, et al., 1997; Cheng & Hamid, 1997; Lai & Yue, 2000; Suzuki, et al., 2000; Wong, et al., 2003).\

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Table 3. Item-total correlations and factor loadings of all 35 items of the SLEI scales

		Item-Total Correlation		Factor Loading	
Scale	**Item no.**	**Actual**	**Preferred**	**Actual**	**Preferred**
Student Cohesiveness	1	0.58	0.59	0.73	0.75
	6R*	0.29	0.20	0.28	0.12
	11	0.47	0.58	0.62	0.72
	16	0.49	0.47	0.58	0.61
	21	0.49	0.55	0.63	0.72
	26R*	0.22	0.17	0.19	0.09
	31	0.52	0.57	0.67	0.73
Open-Endedness	2*	0.17	0.40	0.30	0.60
	7	0.37	0.52	0.49	0.63
	12*	0.18	0.37	0.25	0.47
	17	0.45	0.49	0.61	0.59
	22	0.43	0.49	0.58	0.58
	27R*	-0.09	-0.32	-0.05	-0.37
	32	0.45	0.51	0.60	0.65
Integration	3R +	0.42	0.34	0.62	0.68
	8R*	0.38	0.25	0.27	-0.04
	13	0.36	0.29	0.53	0.60
	18	0.30	0.28	0.55	0.63
	23R*	0.30	0.01	0.19	-0.29
	28	0.40	0.36	0.65	0.68
	33R*	0.34	0.27	-0.24	-0.02
Rule Clarity	4	0.38	0.35	0.59	0.57
	9R*	0.04	-0.08	-0.04	-0.29
	14	0.43	0.35	0.57	0.46
	19	0.43	0.36	0.63	0.63
	24R*	0.10	-0.06	0.02	-0.26
	29	0.33	0.36	0.51	0.60
	34	0.26	0.37	0.46	0.62
Material Environment	5R +	0.50	0.54	0.60	0.59
	10*	0.25	0.42	0.29	0.46
	15R +	0.48	0.60	0.57	0.68
	20R +	0.53	0.62	0.63	0.69
	25R +	0.49	0.61	0.59	0.69
	30	0.41	0.53	0.49	0.60
	35	0.49	0.59	0.60	0.66

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R Items are negatively worded in original version of the SLEI scales

(+) Items changed to positive worded items after pilot test

* Items were deleted in calculating scale means

The SLEI has previously been validated and applied in many studies (Fraser, McRobbie & Giddings 1993; Fisher, Henderson & Fraser, 1997; Fraser & McRobbie, 1995; Wong & Fraser 1996; Lee & Fraser 2002; Tsai 2003). The factor structure of the items was known. Therefore a prior assumption of the loading of the items on different factors could be made. To find out the item factor loadings, a confirmatory factor analysis using AMOS was conducted. Each item was allowed to load on one factor only. The errors associated with all items were posited to be uncorrelated. At first, each scale was tested separately. The model fit of the confirmatory factor analysis was evaluated by the Goodness-of-fit (GFI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA). GFI and CFI vary between 0 and 1. A value over 0.9 indicates an adequate fit whereas a value above 0.95 is a good model fit. A RMSEA value between 0.10 and 0.05 is an acceptable fit. If RMSEA is less than 0.05, it suggests a good model fit. The fit indices were shown in Table 4. In the study, the fit indices were generally acceptable except the Integration scale, whose CFI indices were the only fit indices close to adequate fit. The factor loadings were shown in Table 3. It was found that items having small item-total correlations were generally low in factor loadings. Therefore eleven items (items 6, 26, 2, 12, 27, 8, 23, 33, 9, 24, 10) with relatively low item-total correlations and factor loadings in the perceptions of either actual or preferred environments on their own scale were removed in the subsequent analysis.

Table 4. Fit indices for the confirmatory factor analysis of all 35 items of the SLEI scales

		Actual			Preferred		
Scale	**No. of item**	**GFI**	**CFI**	**RMSEA**	**GFI**	**CFI**	**RMSEA**
Student Cohesiveness	7	0.997	0.947	0.072	0.957	0.915	0.107
Open-Endedness	7	0.973	0.876	0.078	0.972	0.931	0.081
Integration	7	0.890	0.653	0.161	0.893	0.703	0.164
Rule Clarity	7	0.965	0.853	0.091	0.957	0.854	0.105
Material Environment	7	0.994	0.989	0.030	0.987	0.981	0.051
Student Cohesiveness	7	0.997	0.947	0.072	0.957	0.915	0.107

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The remaining 24-item data set was fitted again by each scale separately. Table 5 showed that the fit indices were improved to a very good fit. When a five-factor orthogonal model was tested, the fit indices were not satisfactory. If the five scales were allowed to correlate, this model fitted the data well (Table 5). The correlations among the five scales were shown in Table 6.

Table 5. Fit indices for the confirmatory factor analysis of the remaining 24 items of the SLEI scales

		Actual			Preferred		
Scale	**No. of item**	**GFI**	**CFI**	**RMSEA**	**GFI**	**CFI**	**RMSEA**
Student Cohesiveness	5	0.996	0.993	0.042	0.997	0.997	0.033
Open-Endedness	4	0.997	0.992	0.045	0.999	0.998	0.029
Integration	4	0.999	0.998	0.027	0.998	0.997	0.035
Rule Clarity	5	0.997	0.993	0.031	0.996	0.991	0.039
Material Environment	6	0.997	0.995	0.025	0.990	0.984	0.055
Orthogonal model	24	0.795	0.618	0.100	0.722	0.620	0.117
Correlated model	24	0.937	0.904	0.051	0.940	0.936	0.049

Table 6. Correlations among scales in the correlated model fit

Scale	**Student Cohesiveness**		**Open-Endedness**		**Integration**		**Rule Clarity**		**Material Environment**	
	Actual	**Preferred**	**Actual**	**Preferred**	**Actual**	**Preferred**	**Actual**	**Preferred**	**Actual**	**Preferred**
Student Cohesiveness	1.00	1.00								
Open-Endedness	0.04	0.63	1.00	1.00						
Integration	0.76	0.89	0.23	0.74	1.00	1.00				
Rule Clarity	0.82	0.85	0.02	0.64	0.93	0.94	1.00	1.00		
Material Environment	0.74	0.88	0.18	0.67	0.87	0.91	0.93	0.91	1.00	1.00
Student Cohesiveness	1.00	1.00								

When correlations were allowed among all scales, the final factor loadings of the 24 items were shown in Table 7. For this very restrictive model of which 120 possible factor loadings (24 items x 5 factors), 96 of them were set to zero. All the three fit indices, GFI, CFI, and RMSEA, indicated that it was a good fit. The percentage of variance explained by each factor was shown at the bottom of Table 7. The perceptions of the actual and preferred environments accounted for 35.08%

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and 41.06% respectively.

Table 7. Standardized factor loadings of the correlated model fit

	Standardized factor loading									
Item no.	Student Cohesiveness		Open-Endedness		Integration		Rule Clarity		Material Environment	
	Actual	Preferred	Actual	Preferred	Actual	Preferred	Actual	Preferred	Actual	Preferred
1	0.71	0.74								
11	0.64	0.73								
16	0.57	0.62								
21	0.64	0.71								
31	0.69	0.74								
7			0.49	0.60						
17			0.62	0.59						
22			0.59	0.56						
32			0.59	0.71						
3					0.62	0.67				
13					0.58	0.60				
18					0.54	0.64				
28					0.66	0.69				
4							0.58	0.57		
14							0.57	0.48		
19							0.62	0.69		
29							0.50	0.56		
34							0.50	0.60		
5									0.58	0.59
15									0.57	0.68
20									0.60	0.67
25									0.59	0.68
30									0.56	0.64
35									0.58	0.67
Eigenvalue	2.10	2.51	1.32	1.52	1.44	1.68	1.54	1.70	2.02	2.57
% of variance	8.76	10.46	5.51	6.34	6.00	7.02	6.42	7.08	8.40	10.70

All factor loadings not shown are set to zero. The sample consisted of 1932 students.

After the factor structure was checked by confirmatory factor analysis, the reliability was re-calculated using the remaining 24 items for both individual and

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class means as the unit of analysis. The reliability coefficients showed considerable improvement (Table 8).

Table 8. Internal consistency reliability (Cronbach alpha coefficient), discriminant validity (mean correlation with other scales) and ability to differentiate between classrooms (ANOVA results) for the individual as the unit of analysis

Scale	No. of items	Unit of analysis	Alpha reliability		Mean correlation with other scales		ANOVA eta^2
			Actual	Preferred	Actual	Preferred	Actual
Student Cohesiveness	5	individual	0.78	0.83	0.44	0.64	0.145**
		class mean	0.93	0.96	0.54	0.84	
Open-Endedness	4	individual	0.66	0.71	0.09	0.48	0.153**
		class mean	0.87	0.84	-0.07	0.66	
Integration	4	individual	0.69	0.74	0.50	0.66	0.15**
		class mean	0.93	0.92	0.64	0.85	
Rule Clarity	5	individual	0.68	0.72	0.49	0.62	0.167**
		class mean	0.91	0.88	0.57	0.81	
Material Environment	6	individual	0.75	0.82	0.50	0.66	0.155**
		class mean	0.91	0.95	0.57	0.83	

** $p < 0.01$

The sample consisted of 1932 students in 58 classes.

The eta2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

Mean correlation with other scales was used as a convenient index of discriminant validity. The values ranged from -0.07 to 0.64 in the actual environment and 0.48 to 0.85 in the preferred environment. The values suggested there were correlations among some of the scales which were also found in the confirmatory factor analysis. It was noted the mean correlation calculated from Table 6 was larger because in confirmatory factor analysis, there was no cross-loadings of the items on other scales. Any correlation that existed among items had to be taken up by the factor correlation (Brown 2006, p.92). The correlations among the scales in the preferred environment were larger than in the actual environment.

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The ability of the SLEI to differentiate perceptions of students in different classes is an important characteristic of the measuring instrument. Students of the same class should perceive the scales relatively similar and the mean within-class should vary from class to class. The sensitivity of the scales was checked by one-way ANOVA with each scale as dependent variables and class as an independent variable. The eta squared values ranged from 0.145 to 0.167 indicated that the scales were able to differentiate students' perceptions between different classes.

Students' perceptions of the laboratory learning environments

To find out the students' perceptions of the actual and preferred laboratory learning environments, the average item means and the differences of the five scales were calculated. T-test and Cohen's d effect size were used to assess the statistical significance and the magnitude of the effect (Table 9). The results in Table 9 indicated that there were statistically significant differences ($p < 0.01$) in the students' perceptions of the actual and preferred laboratory learning environments except the Student Cohesiveness scale. The effect size of the differences ranged from 0.05 (small effect) to 2.99 standard deviation (large effect). When the unit of analysis was individual, the largest effect (-1.03 standard deviation) was found in Open-Endedness scale. The mean score of the Open-Endedness scale (2.59) was the lowest in the actual environment. A rating between 2 and 3 meant that the events as described by the items on the scale happened between "Seldom" and "Sometimes". The mean score of the Open-Endedness scale in the preferred environment (3.43) was also the lowest among all the scales. A rating between 3 and 4 meant that the events as described by the items on the scale happened between "Sometimes" and "Often". The largest differences among all the scales suggested that the students were not satisfied with the current practice and preferred a more open approach in the laboratory learning activities. The mean score of the Student Cohesiveness scale was the highest of all the scales in the actual environment (3.77) and the second highest (3.73) in the preferred environment. The results suggested that students perceived good relationships among the peers. The difference between the perceptions of the actual and preferred environments was not statistically significant and the effect size (0.05 standard deviation) was also small. Practically the perceptions of the actual and preferred environments of this scale were the same. Small but notably differences were found in the Integration scale (-0.22 standard deviation), the Rule Clarity scale (0.19 standard deviation), and the Material Environment scale (-0.36 standard deviation).

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The mean scores of the Integration scale (3.49 in “actual” and 3.65 in “preferred”), the Rule Clarity scale (3.75 in “actual’ and 3.63 in “preferred”), and the Material Environment scale (3.58 in “actual’ and 3.85 in “preferred”) in the actual and preferred environments were all between “Sometimes” and “often”. Figure 1 plotted the average item means of the scales in the actual and preferred environments of the 1932 students.

Table 9. Average item mean, average item standard deviation and the difference between students’ perceptions of the actual and preferred laboratory environments on the SLEI scales

Scale	No. of item	Unit of analysis	Average item mean		Average item standard deviation		t	Effect size Cohen's d
			Actual	Preferred	Actual	Preferred		
Student Cohesiveness	5	individual	3.77	3.73	0.69	0.84	2.25	0.05
		class mean	3.74	3.70	0.28	0.30	1.32	0.12
Open-Endedness	4	individual	2.59	3.43	0.78	0.84	-36.29**	-1.03
		class mean	2.60	3.42	0.31	0.24	-16.66**	-2.99
Integration	4	individual	3.49	3.65	0.65	0.76	-9.36**	-0.22
		class mean	3.47	3.63	0.26	0.28	-5.30**	-0.58
Rule Clarity	5	individual	3.75	3.63	0.63	0.72	7.99**	0.19
		class mean	3.73	3.61	0.27	0.23	4.49**	0.47
Material Environment	6	individual	3.58	3.85	0.67	0.80	-13.79**	-0.36
		class mean	3.57	3.82	0.27	0.30	-7.03**	-0.88

** $p < 0.01$

Sample size = 1932 students

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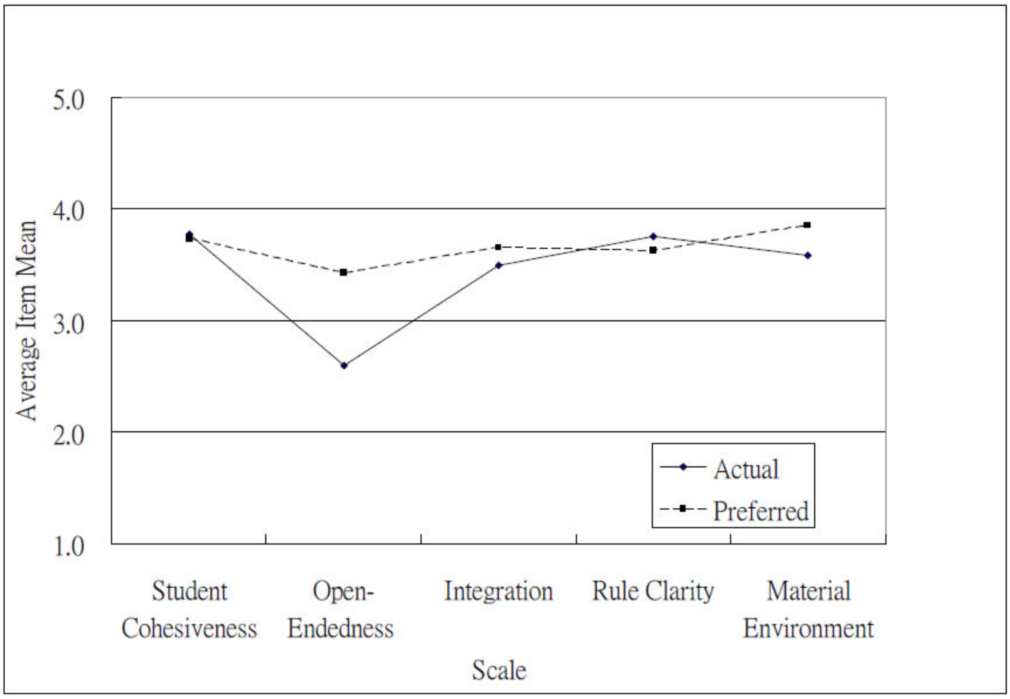

Figure 1. Average item mean of students' perceptions of the actual and preferred laboratory environments on the SLEI scales

Discussions

Student Cohesiveness

The Student Cohesiveness scale describes the extent to which students know, help and are supportive of one another. The results showed that the situations described in the items took place quite often. Results using class mean as the unit of analysis were similar to those using individual as the unit. When teachers were asked to comment about the Student Cohesiveness, they felt that students should generally get along well with each other. They did not think that there was any problem for the students to get to know each other in the class because students spent much time together in the schools. In Hong Kong the students stay together for the whole year for all subjects. They have a fixed seating plan in the classroom as well as in the laboratory. The grouping of students in the laboratory is also fixed. They have lots of time staying together throughout the year. No wonder they know each other so well! With this class structure, students are easy to cultivate close bonds with their classmates. This high level of cohesion had the potential for cooperative learning in small groups in scientific investigations (Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994), and the benefits of positive social interactions in inquiry learning were reported in a number of research studies (Okebukola & Ogunniyi, 1984; Lazarowitz

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& Karsenty 1990; DeCarlo & Rubba, 1994; Tobin, 1990). Although high cohesion among students is common in Hong Kong schools, some teachers do not seem to take such an advantage into their teaching as suggested by the low scores on the Open-Endedness scale in this study.

Open-Endedness

The Open-Endedness scores were the lowest of all the scales in SLEI. Similar findings were reported in Taiwan, Korea and Singapore (Tsai 2003; Lee & Fraser 2002; Wong & Fraser 1996). It was common that students just followed laboratory work instructions of the worksheet, or did some observations for which teachers had already explained or described to them in detail (Hodson, 1990; Hofstein & Lunetta, 1982; 2004). The use of laboratory activities by the teachers was affected by their epistemological belief. If the teachers' view of science as a body of factual knowledge and students as receivers of such knowledge from teachers, it was likely that the purposes of the laboratory work were to demonstrate and verify scientific principles (Kang & Wallace, 2005). Although the science curriculum emphasizes the investigative inquiry approach; the current secondary science students are the first generation of students engaging in such learning process. Thus it is of no surprise that their science teachers, who have little inquiry learning experience, still possess a traditional view of science education with which laboratory activities are only the recipe-driven tasks.

Another reason for the low score in the Open-Endedness scale is that students lack the basic laboratory skills and knowledge to perform open-ended inquiry work. Teachers may not have confidence in students to conduct independent investigative work. Similar concerns were raised in a study in junior secondary science laboratory class in Taiwan (Tsai, 2003). In an interview, a teacher recalled his experience in doing an unauthorized experiment when he was a student:

> *Teacher A: I was playing with a battery and wanted to see what happened when the battery was short-circuited. The teacher reprimanded me of hurting myself and damaging the battery.*

When he was asked whether he would tolerate his students doing the same thing in his class, he replied firmly.

> *Teacher A: I would not allow my students to do so in the laboratory because I am responsible for the safety of my students.*

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Another teacher followed up Teacher A's answer and responded.

> *Teacher B: If the class size is as small as about 20 students I would allow students to do some exploration by themselves. I have confidence in enforcing safety precautions for a small class size in the laboratory. However, under the current normal class size of 40, I would ask the students to do the experiments under strict instructions. My main concern is also safety.*

Without adequate knowledge and skills, accidents could happen to students. The risk of laboratory accidents outweighs the benefit of open-ended inquiry approach of science learning.

Teacher C voiced out another reason for not allowing an open-ended inquiry learning in his laboratory classes.

> *Teacher C: There is insufficient time for open investigations because we have to keep the same pace with other classes taught by other teachers. We have to follow the schedule and cover the same contents so that a common examination could be administrated to all classes.*

The culture of examination oriented learning is deeply rooted in the mind of Hong Kong people (Chan 1996, p. 96). Learning approaches which may lead to unfairness and cause inconvenience for markings in examinations are discouraged. The examination factor, which impedes the implementation of inquiry approach, also exists in countries like Lebanon, Australia and Taiwan (Abd-El-Khalick et al., 2004). Newton, Driver, and Osborne, (1999) also pointed out that time constraints, pressure in implementing the curriculum and parents' expectation discouraged teachers in England from adopting innovations in their science lessons. Thus Hong Kong teachers are not untypical. They share the same concerns with their counterparts in other countries.

Integration

Results showed that the extent of integration between laboratory activities and theory classes was either "Sometimes" or "Often". Although the score in the preferred environment was statistically significantly higher than the score in the actual environment, the difference was small and the students' expectation was comparatively less pronounced than that of the Open-Endedness scale. From my previous experience in visiting schools, I observed that some teachers tended to talk about theories or principles first and arrange the activities at a later time. Students sometimes got lost during the introduction of the theories because they had not seen

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the experiments and the phenomena. The approach of "theory first and verification later" was a rather traditional mode of science teaching in Hong Kong (Holbrook, 1990). This was usually how the teachers learned science in their old school days. It is the past learning experience that shapes how teachers teach (Holbrook, 1990).

The timetable arrangement might also make the integration less favourable. In Hong Kong, schools allocate at least about 40 to 60% of science class periods in laboratory. This is based on the common practice for schools using a six-school-day cycle timetable, i.e. having 2 to 3 laboratory classes out of the 5 class periods. In the interview, teachers wished that there was a better integration between theory and experimental activities, but they also admitted that there was not much they could do about scheduling more laboratory time for the science classes. It was usually handled by the school administrators. Teachers have to cope with the constraint by separating the theory and laboratory activities.

Rule Clarity

In this Rule Clarity scale, students were asked about the extent to which behaviour in the laboratory is guided by formal rules. The scores of the actual and preferred environments were closer to "Often" than "Sometimes" on the scale rating. Students preferred slightly less formal rules though the difference between the actual and preferred environments was small. From my previous experience in visiting schools, I observed that students were excited when they were given the apparatus. Some unmotivated students played around with the apparatus and tried different things which were not instructed by the teachers. In some other lessons, students wanted to have more freedom in working in the laboratories and to explore their own interest in science experiments. Teachers generally tended to be rather strict in enforcing classroom regulations and safety rules because they anticipated serious consequences of laboratory accidents. If the students were often required to follow the rules because of the safety concerns, they perceived the laboratory as a very restrictive environment. Then the learning activities tended to be not open-ended and this was not favoured by the students. So a less preferred Rule Clarity scale rating was probably related to high expectation in Open-Endedness. It was already discussed in the Open-Endedness section that teachers expressed great concerns about laboratory safety. Poor discipline in laboratories increased chances of accidents. No wonder teachers would like students to be obedient in the laboratories, particularly in a class of a size about 30 students.

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In general laboratory and classroom discipline is well maintained in Confucian-Heritage cultures societies like Hong Kong and Taiwan (Aldridge & Fraser, 2000; Thomas, 2006). Disruptive behaviour is not tolerated. However as the western values such as individualism are gradually taking root in Hong Kong, students are demanding more personal freedom to do what they want and beginning to challenge the authoritative image of teachers (examples in Thomas, 2006). The dilemma found in this study was that students preferred less formal rules imposed in the laboratories and teachers would feel uneasy and be afraid of losing control. This was also one of the reasons why science teachers in England resisted innovations in science lessons (Newton, Driver, & Osborne, 1999). Maintaining a well-disciplined learning environment with an atmosphere that was neither too strict nor too much personal freedom require teachers to have good classroom management skills and the cooperation of self-disciplined students. This is particularly important for adopting the inquiry learning approach in the laboratory. However, such perfect match is not always achieved.

Material Environment

The extent to which the laboratory equipment and materials were adequate was rated closer to “Often” than “Sometimes” in the actual and preferred environments. Students expected an even better environment than what they had at present. This might be due to the comparison with other school facilities such as libraries and computer rooms. Laboratories were usually set up when the school was built and comparatively they were old facility in school. More importantly, traditional secondary science laboratories and the standard secondary equipment pool were designed in the 1980s when inquiry learning approach had not been introduced in the curriculum. Equipment and facilities in laboratories in some schools should be upgraded to facilitate the learning of science through open-ended inquiry.

During the teacher interviews, teachers seemed to have complaints about the management and running of the laboratory. All the teachers in the interviews reported that less resource had been allocated for managing the laboratories than for the computer rooms or the libraries, because the local education policy is inclined towards languages and information technology in learning and teaching (EC, 1996; EC, 1997; CDC 2000; EDB 2014). It was not easy to obtain resources in upgrading and replacing damaged equipment in laboratories.. In some schools that I visited during my teaching practice supervision duty, I noticed that some laboratories were neat and tidy although it did not have modernized setting like that in a computer

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room or a well-lighted library. Some other laboratories were stuffed with lots of equipment and students' projects which had been accumulated over the years. Probably there was not enough storage space in schools and the students' projects were kept for display in parents' days or other school functions.

In Hong Kong, laboratory technicians are hired in every school to support the daily laboratory operation and to reduce the heavy workload of teachers. However laboratory technicians are not only responsible for the work in the laboratories but they have to help out other duties assigned by their supervisors, commented by the teachers in the interview. Teachers sometimes could not get the faulty equipment replaced immediately or replenish materials during laboratory activities as the laboratory technicians were sometimes performing duties elsewhere in the school. A teacher commented that a principal who was a former Head of the Science Department in the school thought that it was more cost-effective if laboratory technicians could also serve in other areas such as computer rooms. Hence the laboratory technical support was being diverted to other functions in the school. To handle different open-ended experiments in the laboratory session, laboratory technicians should play a more important role to assist the teacher in the learning and teaching processes. Such human resources are important in promoting the inquiry science learning approach.

Teachers' concerns

Interviews with teachers showed that the teachers also preferred a positive learning environment in the laboratories. They valued student cooperation and support, clear instructions, disciplined students and a well-managed laboratory. Even though the teachers think that a positive learning environment is good for science learning, there was little done by the teachers in providing such environment. The dilemma and barriers faced by the teachers may be explained in terms of the technical dimension, the political dimension, and the culture dimension proposed by Anderson (1996, 2002).

In the technical dimension, the main concerns of the teachers were the material environments and safety in the laboratories. They had complaints about the laboratory management. The safety concern also led the teachers to take extra steps in enforcing classroom discipline for which students usually did not prefer. Space constraint in some old laboratories limited the diversity of activities conducted.

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Solving these problems in the technical dimension may also solve the problems identified in the political dimension. For example, one teacher said that if the class size is smaller, about 20, he could handle the safety concern and would allow more freedom for students to explore. Small class size means more teachers are needed. The increase in staffing of a school would have long term financial implications to the government budget. There are usually fewer disciplinary problems for students of high academic levels, but the discipline is relatively poor in schools with a large number of low academic achievers. Teachers can do little to change that situation because the intake depends on the reputation of the schools as well as the government placement policy (Yung, 1997) which allocates students to different secondary schools according to their academic achievement in primary schools. In general, there is no funding problem for the routine operation of the laboratory because the government provides recurrent funding for the laboratory operations. However the quality of technical support varies greatly among schools and it depends on the management of the school (see examples in Material Environment).

In the cultural dimension, the high cohesion among students commonly found in Hong Kong could have been a positive factor for inquiry investigative approach. However, Chinese students are needed to be trained with more self-study skills and to cultivate the practice of regulating their own learning. The Hong Kong education system is examination-oriented which resembles the Confucian-Heritage culture societies (Biggs, 1990; Morris, 1985; Chan 1996, p. 96). Fairness in examination must be maintained because of high stakes in students' future study and career path. Thus uniformity in teaching and learning opportunities is part of the practice to ensure fairness. The rigid assessment culture, such as centralized subject tests and examinations for all classes at the same grade level, discourages teachers from adopting an open-ended approach in their teaching. It is difficult to up-root this culture. Resistance to change in the assessment culture also comes from many parents and school principals (Holbrook, 1990).

The SLEI instrument

In this study, we translated the SLEI into Chinese and used it in Hong Kong junior secondary schools to assess the students' perceptions of the actual and preferred laboratory learning environments. The adaptation of the SLEI to this study raised some issues which may need to be taken into account in future studies using the SLEI.

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Reliability

Results of this study revealed that some of the items in the SLEI caused low reliability of the scales in the translated SLEI version. These items fell into two categories: negatively worded items and items of which students were contextually unfamiliar.

It was mentioned in previous sections that negatively worded items were causing low reliability of the scales and this effect appeared to be more pronounced in cross-cultural study. The positively and negatively worded items in a unidimensional scale were often found to form separate factors (Marsh, 1996; Dunbar et al., 2000). This had the effect of reduction of reliability. When these items were removed, the reliability was restored. Thus researchers using SLEI in the future may consider using positively worded items only and bidirectional response pattern (Barnette, 2000).

The low reliability of some of the scales might also be caused by students' difficulty in understanding the unfamiliar concepts and situations. This may be due to cultural and contextual differences. One example is an item in the Open-Endedness scale, "In my laboratory sessions, other students collect different data than I do for the same problem" (Open-Endedness scale; item 12 in SLEI). Some students told their teachers that they were confused when reading this item, as they might not have such kind of experience in the process of learning science. Another item in the SLEI which students found puzzling was that "the laboratory class is run under clearer rules than their other classes" (Rule Clarity scale; item 34 in SLEI). These students were used to follow the instructions and rules set by the teachers. They were not yet ready to judge whether the rules were clear or not. If the experiments did not work out properly, they might think that it was their own fault, not because the rules or the instructions were not clear. Particularly for students at the junior secondary level, they have not yet developed a critical mind to judge the clarity of the rules. Another example was that some students were not sure of the meaning of an item "using theory from their regular science class sessions during laboratory activities" (Integration scale; item 18 in SLEI). The word "theory" is an abstract concept. The junior secondary science curriculum in Hong Kong puts more emphasis on science skills and the basic phenomena. Students have not learned many theories yet. Tsai (2003) also reported low reliability in the Open-Endedness scale and suggested that unfamiliarity with the nature of Open-Endedness may be the cause of low reliability. Results of this study seemed to support Tsai's suggestion.

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The cognitive ability of junior secondary students is in the early adolescence stage. Their ability to relate abstractions or hypotheses is starting to increase (Fischer & Bullock, 1984; Eccles, 1999). It was likely that some students with different levels of cognitive development may find some of these items unfamiliar and difficult to understand. Therefore if the instrument is to be used in junior secondary level, the items needed to be re-phrased using words or situations which students could easily comprehend.

Correlation among the scales

It was found that a correlated five-factor model fitted the data better than an orthogonal five-factor model. The model fit suggested some correlations existed among the five scales. Mean correlation with other scales, which was used as a measure of discriminant validity, also showed some correlations among the scales. An underlying factor was suspected to be a possible reason behind that interaction. Previous studies (e.g. Fraser, McRobbie & Giddings, 1993; Henderson, Fisher & Fraser 2000; Lee & Fraser 2002) reported that SLEI measures distinct aspects of the laboratory learning environment. Their orthogonal factor analysis vindicated that the scales were distinct. Although their studies mentioned that there were somewhat overlapping among the scales, this argument was not elaborated. Further studies are needed to clarify and identify the underlying causes of the correlation.

Despite the above problem, the results supported a priori five-factor structure of the Chinese version of SLEI in the data. Internal consistency of the scales was satisfactory and the five scales were also able to differentiate students' perceptions in different classes. The results showed a profile similar to the studies in other culturally connected countries in Taiwan (Tsai, 2003), Korea (Lee & Fraser, 2002) and Singapore (Wong & Fraser, 1996). This gave further support that SLEI is an effective means in measuring the laboratory learning environments.

Conclusions

The statistically significant and noticeable differences between the students' perceptions of the actual and preferred laboratory learning environments in the Open-Endedness scale were the highest among the five scales of the SLEI. Such differences reflected that the students were not satisfied with the present learning environments and preferred to have a more open-ended investigative learning

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approach in their science laboratory classes. The other four scales had only small differences between the actual and preferred environments. Students perceived themselves having good relationships among the peers as indicated by the high scores in the Student Cohesiveness scale in both the actual and preferred environments. The SLEI data in fact showed that the inquiry investigative learning approach as advocated by the science curriculum in Hong Kong seems not to be widely practiced in the junior secondary science laboratory environments.

Interviews with teachers also found that teachers were willing to provide a learning environment for the investigative inquiry approach. However their concerns in the technical dimension, the political dimension and the culture dimension made the teachers hesitate to implement such approach in the laboratory environments.

This study showed that despite high cohesions among students as well as teachers' favourable desire for the investigative inquiry approach in their science teaching, there are a number of other unfavourable factors, such as discipline problems, safety, large class size, laboratory support and examination culture, impeding the actual implementation of the inquiry approach in the science laboratories. Further studies are needed to look into how these factors, especially the issues on discipline problems and examination culture, affect the implementation of the open inquiry learning in laboratory environments, and what the possible resolutions to these issues would be.

The present study found that the SLEI did provide us with a reliable and useful tool to probe students' perceptions on the laboratory learning environments. A translated version of the SLEI with careful use of the wordings is helpful in the understanding of the science learning issue in a local context. Although the problems of the technical dimension, the political dimension as well as the cultural dimension identified in the study are difficult to tackle in the meantime, the study did show us the areas that we could improve in the laboratory learning environments so that an investigative inquiry approach can be implemented effectively. Teachers and school administrators could make use of the results to improve science learning and teaching in their schools.

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