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ABSTRACT

Many have become aware of the need to assess both teachers' and students' perceptions of the learning environment. This study involved 1,592 tenth grade students and their teachers (n=56) in a study that investigated four aims: (1) to cross validate a slightly modified version of the actual and preferred versions of the Science Laboratory Environment Inventory (SLEI) for assessing teachers' and students' perception of the learning environment in chemistry laboratory classes in the Singapore secondary school; (2) investigate the differences in perception of the actual and preferred chemistry laboratory environments between teachers and students, students of different streams, and male and female students; (3) examine associations between students' attitudes towards chemistry and their perceived laboratory environments; and (4) compare the science laboratory environments in Singapore with those of Australia, the United States, Canada, England, Israel, and Nigeria. The results revealed that: (1) perceptions of students and teachers differed; (2) preferred perceptions were generally more favorable than actual perceptions; (3) students from different streams differed only in their preferred perceptions; and (4) females held more favorable perceptions than males. Positive associations were found between the nature of the chemistry laboratory environment and the students' attitudinal outcomes. (ZWH)

Science Laboratory Classroom Environments and Student Attitudes in Chemistry Classes in Singapore

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ABSTRACT

This study had four aims. Firstly, it involved crossvalidating a slightly modified version of the actual and preferred versions of the *Science Laboratory Environment Inventory (SLEI)* (Fraser *et al.*, 1992a, 1993) for assessing teachers' and students' perceptions of the learning environment in chemistry laboratory classes in the Singapore secondary school. Secondly, it investigated the differences in perceptions (if any) of the actual and preferred chemistry laboratory environments between teachers and students, students of different streams, and male and female students (i.e., determinants of classroom environments). Thirdly, the study examined associations between students' attitudes towards chemistry and their perceived laboratory environments (i.e., effects of classroom environments). Fourthly, it compared the science laboratory environments in Singapore with those of Australia, the USA, Canada, England, Israel and Nigeria.

The sample consisted of 1,592 final year secondary school (i.e. tenth grade) students studying chemistry and their chemistry teachers in 56 classes from 28 randomly selected coeducational government schools of similar standard in Singapore. The laboratory environment instrument was found to be reliable and valid for assessing students' and teachers' perceptions of their chemistry laboratory classroom environment, and provided crossvalidation support for use in Singapore.

The investigation of the determinants of environment perceptions revealed that perceptions of students and teachers differed; that preferred perceptions were generally more favourable than actual perceptions; that students from different streams differed only in their preferred perceptions; and that females held more favourable perceptions than males. Positive associations were found between the nature of the chemistry laboratory classroom environment (except Open-Endedness) and the students' attitudinal outcomes. Finally, similarities and differences were found between the science laboratory classroom environment in Singapore and those of the other countries.

BACKGROUND

Classroom Environment Research

Educational environment research has grown out of the research studies of Rudolf Moos and Herbert Walberg since the late 1960s and early 1970s. Rudolf Moos was renowned for his work in social climate scales, including those for psychiatric hospitals (Moos & Houts, 1968) and correctional institutions (Moos, 1968). This then led on to the development of the well-known *Classroom Environment Scale (CES)* (Moos, 1974; Moos & Trickett, 1987). On the other hand, Herbert Walberg began his research in this area with the development of the widely used *Learning Environment Inventory (LEI)*. This instrument was developed as part of his research work with the Harvard Project Physics (Anderson & Walberg, 1974). This pioneering work of Moos and Walberg has acted as a springboard to a large number of studies on classroom environment which has been well documented in various sources including books by Moos (1979), Walberg (1979), Fraser (1986a), Fraser and Walberg (1991), monographs by Fraser (1986b, 1987, 1988), a guest-edited journal issue by Fraser (1980a), an annotated bibliography by Moos and Spinrad (1984), and literature reviews by Chavez (1984) and Fraser (1989, in press).

All the classroom environment studies mentioned above were concerned with measuring and investigating the perceptions of psychosocial characteristics of the learning environment in primary, secondary and tertiary classrooms. Although many of these studies were undertaken in science classrooms, it was felt that the available instruments used in the above studies were of limited appropriateness and applicability for measuring the perceptions of the science laboratory classroom environment. Because of the uniqueness and vital importance of the science laboratory in science education, it was thus imperative that a special instrument should be developed for assessing perceptions of it. The *Science Laboratory Environment Inventory (SLEI)* thus was developed to do just this (Fraser *et al.*, 1992a, 1993). Its development has facilitated the expansion of research specifically in science laboratory clasroom environment which still is in its infancy. The SLEI comprises five scales, of seven items each, which assess the areas of Student Cohesiveness, Open-endedness, Integration, Rule Clarity and Material Environment.

It is indeed timely that such an instrument is available for use with science laboratory classes because previous research on science laboratory instruction has focused on comparing one method of laboratory work with another, or with conventional classroom teaching over relatively short periods of time (Hofstein & Lunetta, 1982). DeCarlo and Rubba (1991) also reported that research in this area has not been comprehensive. For example, not enough is known about the effects of laboratory instruction on students' learning and attitudes. Now, with the availability of the SLEI, students' perceptions of laboratory classroom environment can be assessed easily. Information from the SLEI permits science educators and teachers to investigate the impact of laboratory classes on students' outcomes, and can help to guide improvements in laboratory environment settings. This in turn can contribute to the improvement of teaching and learning in science laboratory classes (Hofstein & Lunetta, 1982; Lehman, 1989).

Recent research on laboratory classroom environments using the SLEI in Australia has indicated that the dimensions of the SLEI were related positively with student attitudes (McRobbie & Fraser, in press). In a previous cross-national study involving six countries (Australia, the USA, Canada, England, Israel and Nigeria), Fraser *et al.* (1992a) reported similar results. These findings are educationally important because they suggest how to promote positive attitudes among students by creating laboratory environments that stress those areas that have been found empirically to be associated with student attitudes.

In the cross-national study, an examination of sex differences on SLEI scores also was made. Consistent differences between the male and female students' perceptions of their science laboratory classroom environment were found. This finding is also of importance because it suggests how teachers could handle their laboratory procedures more fairly, giving both males and females equal opportunities for participation.

The Singapore Scene

Singapore is an island state with a population of 2.6 million. She has virtually no natural resources except her people. In order for her people to survive and prosper, they must "make themselves relevant to the world and provide services and products which are required by the international community" (Tan, 1990). To achieve this goal, a good education system is needed. That is why the Singapore government has made education one of its top priorities.

The Singapore education system is a highly centralised one. The curriculum to a large extent is prescribed by the Ministry of Education because of the common national examination 'hurdles' that need to be crossed in order to move from the primary school to secondary school (i.e., grade 6 to grade 7), from secondary school to pre-university (i.e., grade 10 to grade 11), and from pre-university to tertiary level (i.e., grade 12 to college).

Formal schooling begins at the age of six years and spans a period of at least 10 years. At the end of six years of primary education, students' performance in a national examination is used as a basis for channelling them into one of three streams in the secondary school (i.e., students are divided into different curricular tracks or courses according to their ability). The three streams are termed 'special', 'express' and 'normal'. The 'special' and 'express' streams comprise the higher-ability students and are given four years to prepare for the national examination. The 'normal' stream students, who are mainly of average ability, are given five years to prepare for the same examination. Based on the results of this examination, those who qualify go on to pre-university. At the end of two or three years, the students sit for another national examination. Their results will determine their eligibility for tertiary education; students who fail to qualify join the work force.

An important feature in the Singapore education system is that, besides English Language, the mother tongue (Mandarin, Malay or Tamil) and Mathematics, Science is a compulsory subject in the primary and secondary school curriculum. This has been especially important since she moved from a labour-intensive economy to a highly technological one. Research into science education is thus important as it provides vital information to science educators at all levels as to how science education can be further improved for the betterment of the learners and in turn for the society as a whole. And in a highly competitive achievement-oriented educational system like Singapore's, such information indeed is sought after.

Science education research in Singapore for the past 10 years was reviewed by Toh (1993). The types of studies ranged from those which looked at learning difficulties experienced by students in studying science to studies which dealt with the correlations between science achievement and general abilities, sex of student and attitudes towards science. Lately, there also has been a few studies which investigated the factors affecting students' performance in laboratory investigations. However, classroom environment research has been almost non-existent in Singapore (see Teh & Fraser, 1993), and no study specifically of science laboratory classroom environments has been reported previously. Thus, this study of chemistry classes is an attempt to mark the beginning of this field of research in science education in Singapore. It is felt that findings from studies such as this not only would complement the work already done and still being done, but would provide a more complete picture of the process of science education existing in Singapore.

OBJECTIVES OF THE STUDY

The objectives of the study were:

1. to crossvalidate the *Science Laboratory Environment Inventory (SLEI)*, in its modified form, the *Chemistry Laboratory Environment Inventory (CLEI)*, for use in chemistry laboratory settings in the Singapore secondary school.

2. to investigate some determinants of perceptions of chemistry laboratory environments, particularly differences between the perceptions of teachers and students, of males and females, and of students in different streams.

3. to determine if the nature of the chemistry laboratory environment has an effect on the attitude of the students towards chemistry.

4. to compare the science laboratory environments in Singapore with those of other countries for which data already exist, namely, Australia, the USA, Canada, England, Israel and Nigeria.

SAMPLE

The sample consisted of 1,592 final year secondary school (i.e., tenth grade) chemistry students from both the 'express' and 'normal' streams and their chemistry teachers. Fifty-six classes (56) from 28 randomly selected coeducational government schools of similar standard in Singapore were selected. From every school, one secondary 4 'express' and one secondary 5 'normal' class were selected. In these classes, chemistry was taught as one half of a subject called 'Science'. The other half of the subject was physics. The teacher data comprised 56 sets of responses to the questionnaires, one for each of the 56 classes which took part in the present study.

INSTRUMENTS

Two instruments were used in this study. The chemistry laboratory classroom environment perceptions of the teachers and the students were measured using the *Chemistry Laboratory Environment Inventory (CLEI)*. The students' attitudes towards chemistry were assessed using the *Questionnaire of Chemistry-Related Attitudes (QOCRA)*.

The CLEI

The CLEI is a modified version of the SLEI, which was described previously in this paper. The modification of the instrument only entailed replacing the word 'science' with 'chemistry' throughout. The rest of the wording of items remained unchanged.

The original SLEI comes in two forms, the Class form and the Personal form. The Class form assesses the students' perceptions of the class as a whole, while the Personal form involves assessing the students' perception of his/her own role in the laboratory class.

In the present study, the chemistry laboratory environment as perceived by the students was measured using the actual and preferred versions of the Personal form of the SLEI. The Personal form was chosen instead of the Class form because it was felt that the Personal version would be more sensitive in assessing the differences between subgroups within a class (e.g., males and females) (Fraser & Tobin, 1991), which was one of the areas being investigated in this study. The actual and preferred versions of the Personal form were retitled the Student Actual Form and the Student Preferred Form, respectively.

For the teachers, the actual and preferred versions of the Class form of the SLEI were modified for their use. These were renamed the Teacher Actual Form and the Teacher Preferred Form, respectively. In this set of forms, some of the statements were reworded in terms of how a teacher would perceive a situation rather than how a student perceived it. However, the original meaning of the statements was left intact.

As in the SLEI, the original form of the CLEI used in this study consisted of 35 items, with seven items in each of the five scales: Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment. Items are arranged in a cyclic order. Out of the 35 items, 13 of them are worded and scored in the reverse manner. However, following the item analysis described later in the Results section, two items were deleted to form a final form of the CLEI containing 33 items altogether. A five-point scale, with the alternatives of Almost Never, Seldom, Sometimes, Often and Very Often, is used for the responses.

The QOCRA

Students' attitudes towards chemistry were assessed using the QOCRA, which is a shortened and modified version of the *Test of Science-Related Attitudes (TOSRA)* (Fraser, 1981). The original TOSRA questionnaire consisted of 70 items designed to measure seven distinct science-related attitudes among secondary school students. However, for the purposes of this study, the only three of these scales considered were: Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, and Enjoyment of Science Lessons. They were renamed Attitude to Scientific Inquiry in Chemistry, Adoption of Scientific Attitudes in Chemistry, and Enjoyment of Chemistry Lessons.

In addition, because the present study only assessed chemistry-related attitudes, the word 'science' was replaced with 'chemistry' for all items. But the original meaning of the statements remained unchanged.

Like the SLEI, a five-point response scale also is used for the QOCRA. The response alternatives are Strongly Agree, Agree, Not Sure, Disagree and Strongly Disagree. Out of the 30 items in the QOCRA, half of them are worded in the reverse manner.

PROCEDURES

The researcher administered the instruments to 28 secondary 4 'express' and 28 secondary 5 'normal' stream classes of students and their teachers in the 28 coeducational government secondary schools in Singapore during the first term of the school year (i.e., January-March) 1993. The students completed three questionnaires, namely, the actual and preferred versions of the Student form of the CLEI, and the QOCRA. The teachers completed the actual and preferred versions of the Teacher form of the CLEI. Approximately one hour was required to administer all questionnaires to each class.

METHOD

Crossvalidation of the CLEI

The Student form and the Teacher form of the CLEI were crossvalidated for use with the Singapore sample as part of the main study using the sample of 1,592 final year secondary school students and 56 sets of teacher responses from 56 classes in 28 Singapore coeducational government secondary schools. Item and factor analyses were performed on the data to assess the CLEI's structure and to identify possible 'faulty' items. Furthermore, a series of analyses of variance, using class membership as the independent variable, was carried out for the CLEI (Student/Actual) instrument to examine if the actual version of each of the environment scale was able to differentiate significantly between perceptions of students in different classrooms.

Determinants of classroom environment

The investigation of the determinants of perceptions of chemistry laboratory environment, particularly differences between teachers and students, of students in different streams, and of males and females, was carried out using multivariate analyses of variance (MANOVAs) with repeated measures to analyse the data. To compare the actual and preferred perceptions of the chemistry laboratory classroom environment of students and teachers, a one-way multivariate analysis of variance (MANOVA) with repeated measures was performed, with the set of five CLEI scales as dependent variables and with the 'form' of the instrument (e.g., teacher/actual, student/preferred) as a four-level repeated measures factor. The MANOVA was performed using the students' class mean and the teachers' individual mean as the units of analysis.

When comparing the perceptions of the chemistry laboratory classroom environment of male and female students, and students in the 'express' and 'normal' streams, a two-way multivariate analysis of variance (MANOVA) with repeated measures on one factor for the set of 10 environment scales (five actual and five preferred) as the set of dependent variables was performed. One independent variable was the stream and the repeated measures independent variable was sex. For the analyses involving the investigation of sex differences, only the 50 coeducational classes (out of a total of 56 classes) were considered. The unit of analysis used in these analyses was the sex subgroup means for each class (i.e., male subgroup mean and female subgroup mean for each class). When examining stream differences, the total student cohort of 56 classes was used. In this case, the unit of analysis used was the class mean.

Associations between students' perceptions of their chemistry laboratory classroom environment and their chemistry-related attitudes

Relationships between chemistry laboratory classroom environment perceptions assessed by the CLEI (Actual) and attitudinal outcomes measured by the QOCRA were investigated using three main methods of analyses, namely:

1. simple correlational analyses of relationships between each attitudinal scale and individual environment scales,
2. multiple regression analyses of relationships between each attitudinal scale and the set of environment scales as a whole,
3. canonical analyses of relationships between the set of attitudinal scales and the set of environment scales.

For all the three tests used, analyses were each carried out using the individual student's score as the unit of statistical analysis, and then repeated using the class mean as the unit of analysis.

These methods of statistical measures were chosen because these were the three main methods used in previous research which examined relationships between outcomes and students' classroom environment perceptions. In addition, using similar statistical tests permitted easier comparison of the results from the present study with those of past studies in the same field.

Comparison of the results of previous science laboratory environments studies with those of the present study

The results of the present study were compared with those of the original validation and crossvalidation samples for which data already exist. The areas compared included the student perceptions on all the five SLEI scales, sex differences in perceptions of science laboratory class environment and the environment-attitude associations.

RESULTS

Crossvalidation of the CLEI

The SLEI (Personal form), in its modified form, the CLEI (Student form), was crossvalidated as part of the present study using the sample of 1,592 upper secondary school students in 56 classes. Item and factor analyses were carried out with the data. The results for the item analysis are summarised in Table 1, while that for the factor analysis is given in Appendix A.

TABLE 1

Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for Actual and Preferred Versions of the CLEI(Teacher form), and the CLEI(Student form) for Two Units of Analysis, and Ability to Differentiate between Classrooms

Scale	No. of Items	Unit of Analysis	Alpha Reliability		Mean Correlation with other Scales		ANOVA Results (eta^2)
			Actual	Preferred	Actual	Preferred	Actual
Student Cohesiveness	7	Individual Student	0.681	0.638	0.233	0.345	0.099*
		Student Class Mean	0.831	0.819	0.303	0.542	
		Individual Teacher	0.725	0.593	0.160	0.341	
Open-Endedness	6	Individual Student	0.414	0.581	0.028	0.129	0.082*
		Student Class Mean	0.537	0.660	0.046	0.218	
		Individual Teacher	0.717	0.672	0.136	0.237	
Integration	7	Individual Student	0.685	0.664	0.300	0.313	0.175*
		Student Class Mean	0.872	0.852	0.362	0.550	
		Individual Teacher	0.914	0.665	0.207	0.297	
Rule Clarity	6	Individual Student	0.634	0.570	0.279	0.312	0.194*
		Student Class Mean	0.837	0.816	0.361	0.387	
		Individual Teacher	0.764	0.641	0.242	0.242	
Material Environment	7	Individual Student	0.715	0.769	0.248	0.387	0.178*
		Student Class Mean	0.819	0.914	0.312	0.537	
		Individual Teacher	0.750	0.737	0.270	0.393	

* $p < 0.001$

The student sample consisted of 1,592 upper secondary chemistry students in 56 classes. The student individual score and the student class mean were used as the units of analysis. The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

The teacher data comprised 56 sets of teacher responses, one for each of the 56 classes. The unit of analysis used for the teacher sample was the teacher individual score.

From the item analysis, it was found that two of items, item 24 from the Rule Clarity scale and item 27 from the Open-Endedness scale, had to be discarded due to inconsistent results obtained for the item-scale intercorrelation calculations in both the actual and preferred versions of the CLEI. Scores on item 24 were correlated negatively with its total scale score, while the item-scale correlation for item 27 was close to zero.

With the exception of items 24 and 27, the item analysis justified the retention of all of the other 33 items in the CLEI. Hence, the data obtained for these two items were removed from the main data set and not used in all the analyses in this present study. All statistics obtained were based on a data set which excluded item 24 from the Rule Clarity scale and item 27 from the Open-Endedness scale. Each of the other three scales (Student Cohesiveness, Integration and Material Environment) still comprised seven items each.

Internal consistency (alpha reliability) and discriminant validity (mean correlation of a scale with the other four scales) were obtained for the sample in this present study as indices of scale reliability and discriminant validity. The removal of items 24 and 27 helped to enhance each scale's internal consistency and discriminant validity. A summary of these values obtained separately for the actual and preferred versions of the CLEI and for the two units of analysis (individual mean and class mean) are reported in Table 1. As expected, reliability estimates were higher when the class mean was used as the unit of analysis. On the whole, the statistics obtained were acceptable, though somewhat lower in value than those obtained previously in the original validation sample (Fraser *et al.*, 1992b). For example, alpha ranged from 0.414 to 0.715 for the actual version of the CLEI (Student form) used in this study when using the individual as the unit of analysis, compared with 0.71 to 0.86 in the original validation study.

A series of analyses of variance also was performed on the student data obtained from the CLEI (Actual) instrument. This was done to investigate if each scale had the ability to differentiate significantly between perceptions of students from different classes. This simply means that students within the same class should perceive it relatively similarly, while mean within-class perceptions should vary from class to class. This characteristic was examined for each scale of the CLEI (Actual) using a one-way analysis of variance, with class membership as the main effect and using the individual as the unit of analysis. From the results (see last column of Table 1), it was confirmed that the actual version of each scale differentiated significantly ($p<0.001$) between perceptions of students in different classrooms for the sample in this study. The eta^2 statistic, which represents the amount of variance in the environment scores accounted for by class membership, ranged from 0.082 to 0.194 for the present sample.

With items 24 and 27 omitted, the responses to the remaining 33 items of the CLEI (Actual) instrument for this sample were subjected to separate principal components factor analyses (with varimax rotation) involving the individual student's score as the unit of analysis, the factor structure that evolved replicated to a large extent the structure reported previously for the SLEI (Personal form) by Fraser, Giddings and McRobbie (1992b), with the exception of only a few items. A table which lists the items which were found to have factor loadings greater than 0.30 (which is the minimum value conventionally accepted as meaningful in factor analysis) is given in Appendix A.

With reference to the table in Appendix A, it can be seen that the factor structure of three out of the five scales, namely, Student Cohesiveness, Integration and Material Environment, were replicated exactly. For the Rule Clarity scale, five of the surviving six items had a factor loading greater than 0.30 with its own scale. They are items 4, 14, 19, 29 and 34. Only item 9 from the Rule Clarity scale had a factor loading of less than 0.30. For the Open-Endedness scale, four of the a priori six items had a factor loading greater than 0.30 with its scale; they are items 7, 12, 17 and 22. Items 2 and 32 had factor loadings of less than 0.30.

Although item 2 had a factor loading of less than 0.30 with its own scale (i.e., the Open-Endedness scale), it had a factor loading of greater than 0.30 with the Rule Clarity scale. Also item 28 from the Integration scale and item 31 from the Student Cohesiveness scale had factor loadings greater than 0.30 with both their own scale and with the Rule Clarity scale. As explained earlier in this section, items 24 and 27 were excluded in the analysis because they were found in the item analysis to have unsatisfactory item-scale correlations. On the whole, it appears that the majority of the items had factor loadings greater than 0.30 with their a priori scales, and hence, the results lend support to the factorial validity of the CLEI.

The SLEI (Class form), in its modified form, the CLEI (Teacher form), also was crossvalidated in the present study using the sample of 56 sets of chemistry teacher responses. Item analysis was carried out with the teachers' data. It should be noted that, as a result of the item analysis conducted for the CLEI (Student form) which led to the removal of items 24 and 27 for the subsequent analyses in this present study, these two items also were not retained in the teachers' data set even though they were found to be satisfactory in the item analysis based on the teachers' data. This was done so that the results obtained with the teacher sample could be compared validly with those obtained with the students' data. Hence, the Open-Endedness and Rule Clarity scales contained six items each, whereas the other three scales retained seven items each.

The internal consistency (alpha reliability) and discriminant validity obtained from the item analysis generally were consistent with those obtained previously with the original Class form validation sample (Fraser *et al.*, 1993). A summary of these statistics for the present sample for the actual and preferred versions of the CLEI are also reported in Table 1. In this case, there is only one unit of analysis because we are dealing with an individual teacher in each class.

From the item and factor analyses, the CLEI has been found to be a reliable and valid instrument for assessing students' and teachers' perceptions of their chemistry laboratory classroom environment, and provides crossvalidation support for the SLEI for use specifically in Singapore, in either its actual or preferred version, and using either the individual or the class mean as the unit of analysis.

Determinants of classroom environment: Differences between students and teachers

The actual and preferred perceptions of the chemistry laboratory classroom environment of students and teachers were measured using the CLEI. The CLEI data for the 56 classes were used to generate four sets of environment perceptions scores for each class on each of the five CLEI scales: the class mean of students' actual scores; the class mean of students' preferred scores; the teacher's actual score; and the teacher's preferred score. The means of each set of perception scores calculated across the 56 classes are tabulated in Table 2.

In Table 2, Student Cohesiveness, Integration and Material Environment each contain seven items, scored from 1 to 5, so that the minimum and maximum score possible on each of these scales is 7 and 35, respectively. The remaining two scales, Open-Endedness and Rule Clarity, each contains six items scored from 1 to 5. Thus, the minimum and maximum score possible on each of these two scales is 6 and 30, respectively. Because of this difference in the number of items in the five scales, the average item mean (i.e., the scale mean divided by the number of items in the scale) for each scale was calculated so that there is a fair basis for comparison between different scales. The average item mean for each scale are given in the last two columns of Table 2. These means were used as a basis for constructing the simplified plots of significant differences between forms of the CLEI shown in Figure 1.

The first step in the construction of the classroom environment profiles shown in Figure 1 for each CLEI scale involved the performance of a one-way multivariate analysis of variance (MANOVA) with repeated measures. For these analyses, the 'form' of the instrument (e.g., student/actual, teacher/preferred) constituted a four-level repeated measures factor, while the set of five CLEI scales constituted the dependent variables. Because Wilks' lambda criterion was statistically significant ($p<0.01$), a univariate one-way analysis of variance (ANOVA) for repeated measures was examined for each of the five scales individually. Finally, in cases for which the ANOVA yielded statistically significant results, pair-wise comparisons between different forms of the same scale (e.g., student/actual versus student/preferred, teacher/actual versus teacher/preferred) were performed using t-tests for dependent samples.

This three-step approach for the analysis was taken so as to reduce the Type I error rate associated with the performance of multiple *t*-tests.

TABLE 2

Scale Means and Standard Deviations for Actual and Preferred Versions of the CLEI for Students and Teachers

Scale	No. of Items	Form	Scale Mean		Standard Deviation			Average Item Mean	
			Student	Teacher	Student Individual	Student Class Mean	Teacher Individual	Student	Teacher
Student Cohesiveness	7	Actual	26.96	26.88	4.12	1.28	3.36	3.85	3.84
		Preferred	28.38	30.38	4.24	1.39	3.21	4.05	4.34
Open-Endedness	6	Actual	14.04	11.66	3.08	0.86	3.30	2.34	1.94
		Preferred	17.15	18.36	4.30	1.33	3.75	2.86	3.06
Integration	7	Actual	27.26	27.45	4.05	1.58	5.42	3.89	3.92
		Preferred	27.70	30.43	4.47	1.57	3.11	3.96	4.35
Rule Clarity	6	Actual	22.99	25.79	3.54	1.43	2.90	3.83	4.30
		Preferred	23.42	26.54	3.59	1.26	2.72	3.90	4.42
Material Environment	7	Actual	24.55	25.73	4.81	1.95	4.39	3.51	3.68
		Preferred	28.47	32.27	5.40	2.21	3.38	4.07	4.61

The student sample consisted of 1,592 upper secondary chemistry students in 56 classes.

The teacher sample comprised 56 sets of teacher responses, one for each of the 56 classes.

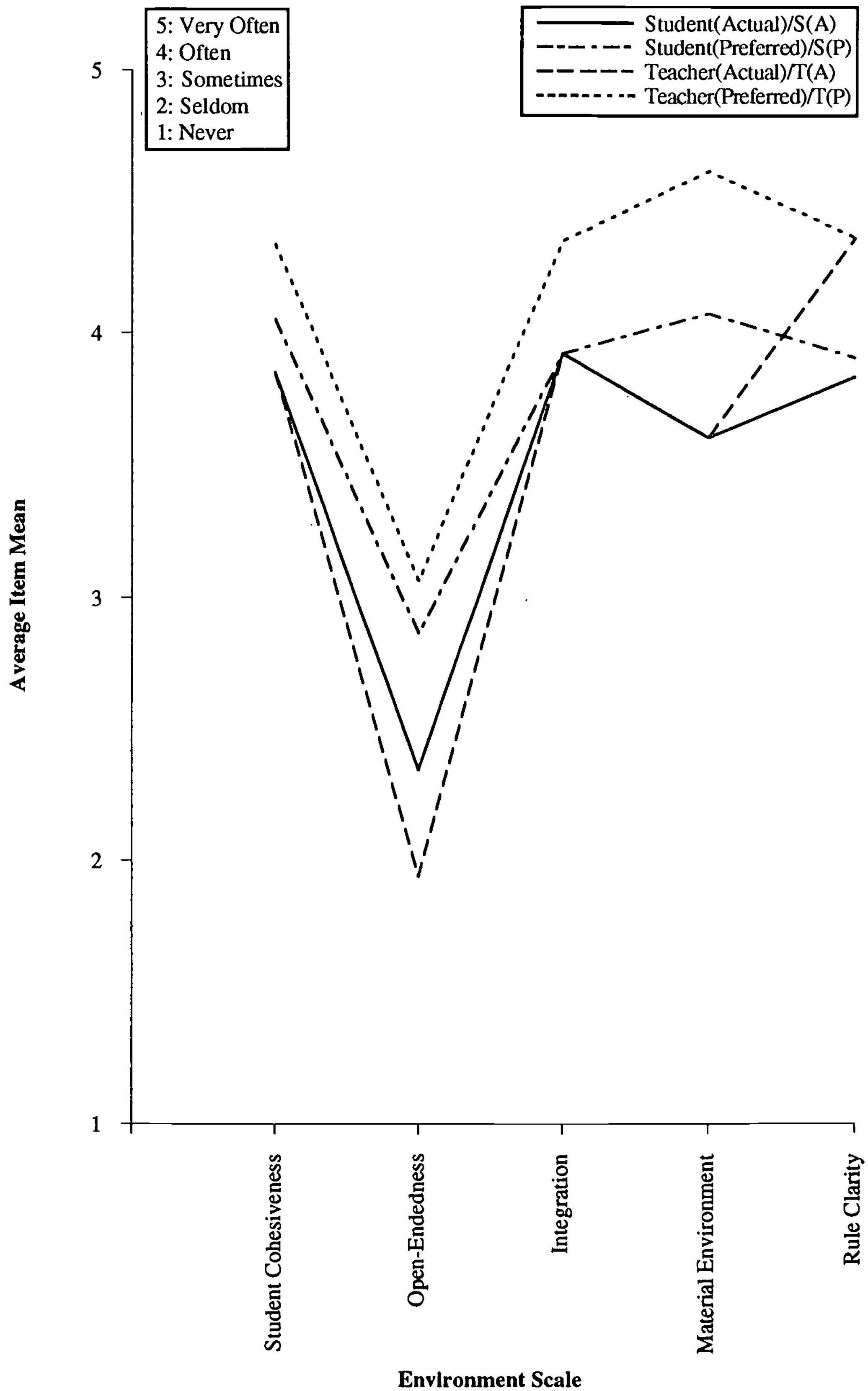
The Average Item Mean was calculated by dividing the scale mean by the number of items in that scale. All the scales have 7 items each, except Open-Endedness and Rule Clarity which have 6 items each.

The average item means shown in Table 2 for each scale in the actual and preferred version of both the Student and Teacher forms of the CLEI were plotted in Figure 1. In an attempt to provide a more parsimonious picture of the differences between scores on pairs of forms of each CLEI scale, it was decided to include only statistically significant differences ($p<0.05$) found in the MANOVA described above when plotting the profiles shown in Figure 1. Hence only the average item means which were significantly different were plotted. Any nonsignificant difference between a pair of forms for a particular scale was represented as a zero difference by averaging the relevant pair of average item mean scores.

The average item means were plotted instead of the scale means because of the difference in the number of items in the five scales. Hence the average item means provided a fair basis for comparison between the different scales. The response alternatives of the CLEI instrument corresponding to the value intervals on the average item mean axis in Figure 1 are as follows: 1 = 'Never', 2 = 'Seldom', 3 = 'Sometimes', 4 = 'Often', and 5 = 'Very Often'.

On comparing the actual ~~and preferred~~ perceptions of the chemistry laboratory classroom environment of students and teachers in Figure 1, it was found that teachers and students tended to have similar perceptions of the levels of Student Cohesiveness, Integration and Material Environment existing in their classes. However, teachers perceived a significantly lower occurrence of Open-Endedness but a significantly higher level of Rule Clarity than their students.

Figure 1: Simplified Plot of Significant Differences between Student(Actual), Student(Preferred), Teacher(Actual) and Teacher(Preferred) Perception Scores



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With regards to their preferred perceptions, students would prefer an environment with greater levels of Student Cohesiveness, Open-Endedness, Rule Clarity and Material Environment. Teachers were also quite similar in their preferences. They also would like an environment with more Student Cohesiveness, Open-Endedness and Material Environment. But the teachers considered the level of Rule Clarity sufficient and would prefer more Integration instead. In general, teachers' perceptions were either similar to or more positive than those of their students on most of the CLEI dimensions. This finding replicated previous classroom environment research to some extent (Moos, 1979; Fraser, 1982). Another interesting pattern which emerged from the present study was that the differences between actual and preferred perceptions of teachers were much greater than the differences for their students. This is clearly depicted in Figure 1 and the values of the average item means given in Table 2.

Determinants of classroom environment : Stream differences and sex differences

The actual and preferred perceptions of students in the 'express' and 'normal' streams, and of male and female students also were compared as a major part of the present study. The first step in the analysis involved a two-way multivariate analysis of variance (MANOVA) with repeated measures on one factor performed for the set of 10 environment scales (five actual and five preferred) as dependent variables . One independent variable was the stream and the repeated measures independent variable was sex. This analysis confirmed that significant differences existed overall between the sexes and between streams. It also showed that there was no significant interaction between sex and stream. This justified an examination of the results of a two-way univariate analysis of variance (ANOVA) for each of the 10 CLEI scales separately. This two-step approach for the analysis was taken so as to help reduce the Type I error rate which may arise from numerous individual significance tests.

The scale means and standard deviations for the actual and preferred perception scores caalculated across 28 'express' and 28 'normal' classes (i.e., total sample of 56 classes) for each of the five CLEI scales are tabulated in Table 3. Similarly, Table 4 contains the same statistics calculated across the 50 coeducational classes for the male and female students' perception scores on the actual and preferred versions of CLEI. As explained in the previous section, the maximum and minimum score possible is 7 and 35 respectively for the Student Cohesiveness, Integration and Material Environment scales; and 6 and 30 respectively for the Open-Endedness and Rule Clarity scales. The average item mean (see section 4.4) for each scale was also calculated and reported in the last two columns of Tables 3 and 4.

Furthermore, in an attempt to provide a parsimonious picture of the differences between the sexes and between the streams, it was decided that only the score differences which were significantly different ($p<0.05$) would be plotted. Figure 2 is therefore the simplified plot of the results in Table 3, while Figure 3 is the plot for Table 4. As in the case for Figure 1, the response alternatives of the CLEI instrument corresponding to the value intervals on the average item mean axis in both of these figures are also as follows: 1 = 'Never', 2 = 'Seldom', 3 = 'Sometimes', 4 = 'Often', and 5 = 'Very Often'.

With reference to Table 3 and Figure 2, it can be seen that there was no significant difference between the actual perception scores of the 'express' and 'normal' stream students for all five CLEI scales. Students from both streams seemed to perceive similar levels of Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment in their existing chemistry laboratory classes. They felt that levels of Student Cohesiveness, Integration and Rule Clarity were close to 'often', while that for Material Environment was between 'sometimes' and 'often', and it was 'seldom' that laboratory activities were open-ended. The reason for this similarity in perceptions held by students from both streams could be that the teachers tend to treat these final year classes, whether they are in the 'express' or 'normal' stream, rather similarly because they both were being prepared for the same examination at the end of the school year. The teachers probably felt that by so doing, neither stream would feel disadvantaged.

TABLE 3

Scale Means and Standard Deviations for the Actual and Preferred Versions of the CLEI for 'Express' and 'Normal' Stream Students

Scale	No. of Items	Form	Scale Mean			Standard Deviation		Average Item Mean	
			Express	Normal	Difference	Express	Normal	Express	Normal
Student Cohesiveness	7	Actual	27.26	27.00	0.26	1.25	1.33	3.89	3.86
		Preferred	29.13	27.77	1.36**	1.14	1.29	4.16	3.97
Open-Endedness	6	Actual	13.92	14.12	- 0.20	0.89	0.84	2.32	2.35
		Preferred	17.38	16.83	0.55	1.26	1.36	2.90	2.81
Integration	7	Actual	27.85	26.83	1.02	1.57	1.46	3.98	3.83
		Preferred	28.40	27.06	1.34**	1.30	1.56	4.06	3.87
Rule Clarity	6	Actual	23.04	22.94	0.10	1.57	1.30	3.84	3.82
		Preferred	23.68	23.16	0.52	1.16	1.31	3.95	3.86
Material Environment	7	Actual	24.72	24.60	0.12	1.92	2.01	3.53	3.51
		Preferred	29.47	27.54	1.93**	1.97	2.04	4.21	3.93

** $p<0.01$

The sample consisted of 1,592 students in 56 classes from 28 schools. Of these, there were 803 students from 28 'express' stream classes and 789 students from 28 'normal' stream classes.

The Average Item Mean was calculated by dividing the scale mean by the number of items in that scale. All the scales have 7 items each, except Open-Endedness and Rule Clarity which have 6 items each.

However, when the preferred perception scores of the two streams were compared, it could be seen clearly from both Table 3 and Figure 2 that there were significant differences ($p<0.01$) between their mean scores for all the CLEI scales except Open-Endedness and Rule Clarity. Relative ot 'normal' stream students, 'express' stream students preferred more Student Cohesiveness, more Integration and a better Material Environment. The effect size for Student Cohesiveness was 1.12 standard deviations, for Integration was 0.94 and for Material Environment was 0.96. For the Open-Endedness and Rule Clarity scales, the preferences of students from both streams were similar.

It is understandable why the 'express' stream students would have higher expectations than their 'normal' stream counterparts. The 'express' stream students are of higher ability, and hence would be more critical of what they receive from their education and would demand more from it. On the other hand, the lower ability 'normal' stream students could be more accepting of what they are being offered, and therefore would be less demanding of the system.

Another interesting feature illustrated in Figure 2 is that the two areas in which students from both streams would like to see the most change are Open-Endedness and Material Environment. They would like open-ended activities to take place 'sometimes' instead of 'seldom', and they would prefer to have a better laboratory environment in which to work a little more 'often'. This result also was reflected when the students' actual and students' preferred perceptions were compared in the previous section for the whole student cohort used in this study.

Figure 2: Simplified Plot of Significant Differences between 'Express' and 'Normal' Stream Actual and Preferred Perception Scores

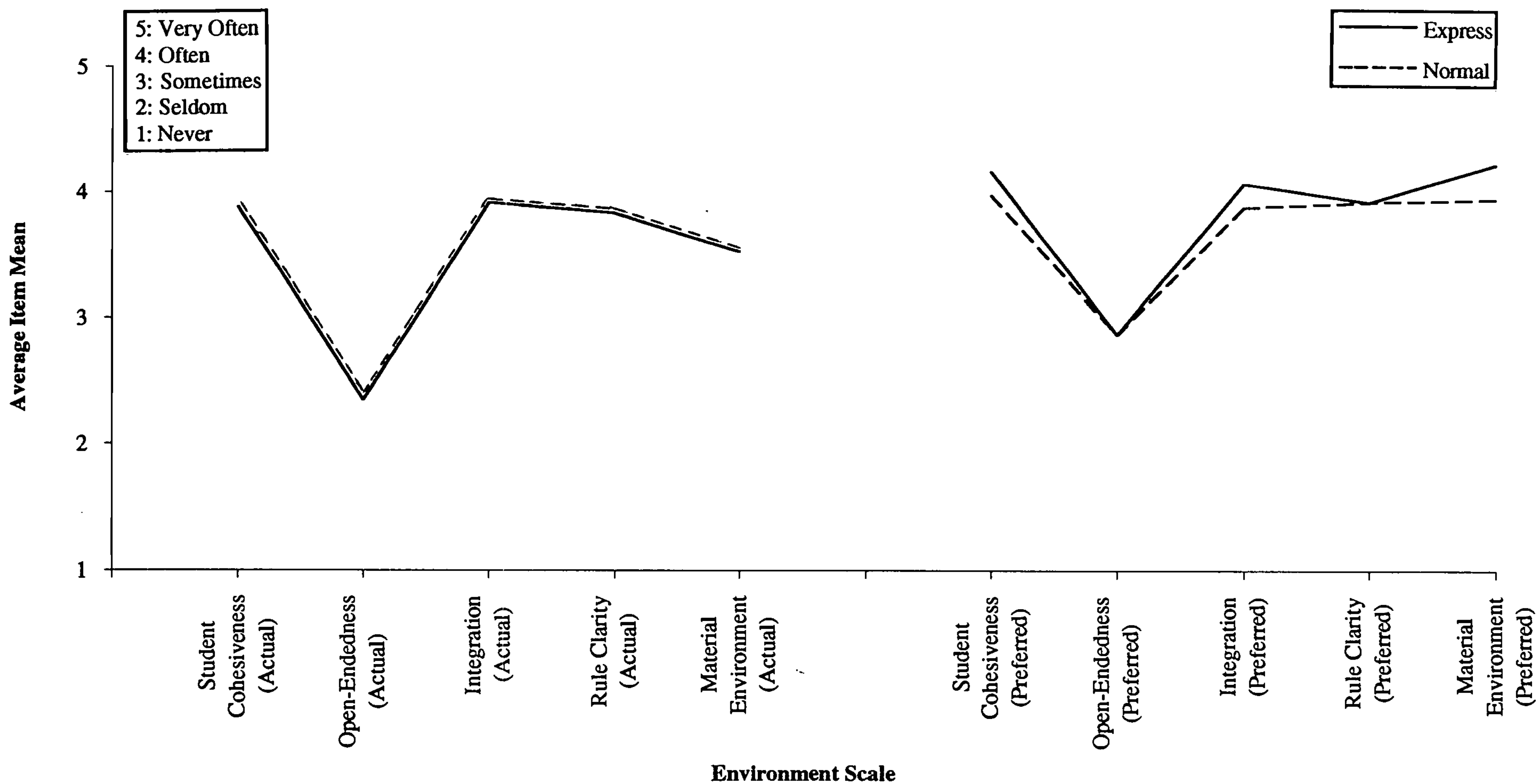

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TABLE 4

Scale Means and Standard Deviations for the Actual and Preferred Versions of the CLEI for Male and Female Students

Scale	No. of Items	Form	Scale Mean			Standard Deviation		Average Item Mean	
			Male	Female	Difference	Male	Female	Male	Female
Student Cohesiveness	7	Actual	26.87	27.15	0.28	1.69	1.45	3.84	3.88
		Preferred	28.14	28.70	- 0.56*	1.82	1.42	4.02	4.10
Open-Endedness	6	Actual	14.25	13.73	0.52**	1.05	1.08	2.38	2.29
		Preferred	17.50	16.83	0.67*	1.89	1.54	2.92	2.81
Integration	7	Actual	27.01	27.77	- 0.76**	1.70	1.64	3.87	3.97
		Preferred	27.27	28.28	- 1.01**	1.95	1.72	3.90	4.04
Rule Clarity	6	Actual	26.27	26.48	- 0.21	1.50	1.76	4.38	4.41
		Preferred	26.36	27.19	- 0.83**	1.65	1.54	4.39	4.53
Material Environment	7	Actual	24.47	24.95	- 0.48	2.43	2.10	3.50	3.56
		Preferred	27.85	29.30	- 1.45**	2.94	2.15	3.98	4.19

* $p<0.05$
** $p<0.01$

The sample size was 1,450 students from 50 coeducational classes in 28 schools. Of these, there were 649 male students and 801 female students. The six single-sex classes were omitted when generating the statistics for this table.

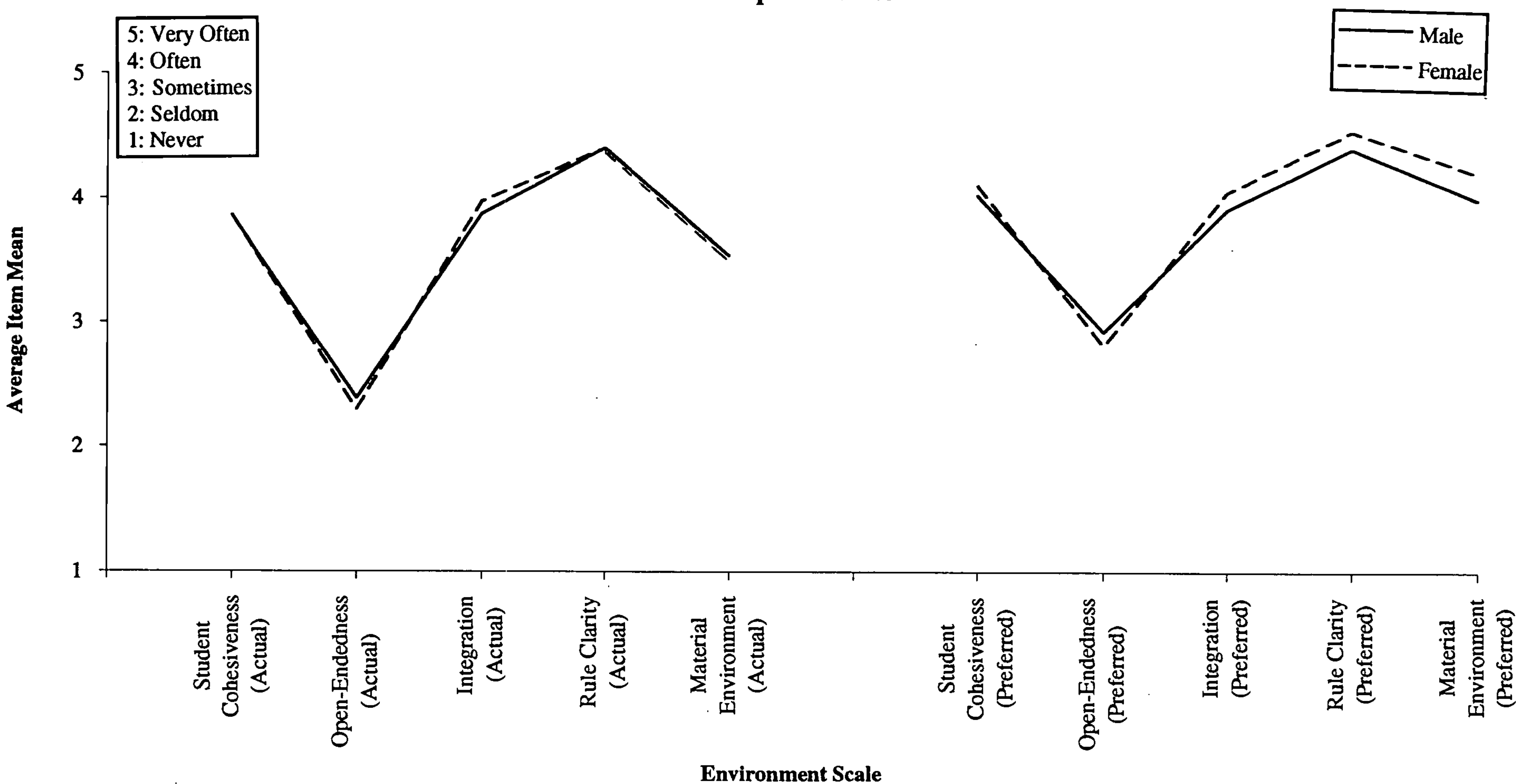
The Average Item Mean was calculated by dividing the scale mean by the number of items in that scale. All the scales have 7 items each, except Open-Endedness and Rule Clarity which have 6 items each.

An examination of Table 4 and Figure 3 shows that male and female students differed significantly ($p<0.01$) for two of the five CLEI scales, namely, Integration and Open-Endedness. Both male and female students agreed that Integration was 'often' practised, but they 'seldom' had open-ended activities in their present laboratory classes. However, female students perceived that Integration was practised more frequently than was perceived by their male counterparts. In the area of Open-Endedness, the male students perceived its occurrence more frequently than the female students. Each of these differences had an effect size of about 0.50 standard deviations.

For the remaining three scales, Student Cohesiveness, Rule Clarity and Material Environment, there was no significant difference between the perceptions of the male and female students. Both groups felt that there was 'often' Student Cohesiveness in their existing classes, that Rule Clarity was practised with a frequency between 'often' and 'very often', and that Open-Endedness 'seldom' occurred.

Figure 3 clearly shows that the differences in preferred perception scores between male and female students differed significantly ($p<0.05$) for all five CLEI scales. Female students had higher levels of preferences than the male students in four of the five CLEI scales, namely, Student Cohesiveness, Integration, Rule Clarity and Material Environment.

Figure 3: Simplified Plot of Significant Differences between Male and Female Actual and Preferred Perception Scores



These differences in perceptions between the sexes amounted to an effect size of approximately 0.35 for Student Cohesiveness, and between 0.50 and 0.60 for Integration, Rule Clarity and Material Environment, all in favour of the female students. This could indicate that female students are less contented with what was happening in their chemistry laboratory classes at present and would like to see a greater improvement in these areas than their male counterparts. However, in the area of Open-Endedness, an effect size of 0.39 in favour of the male students was found.

Once again, as noted previously, the two areas in which students, whether male or female, would like to see the greatest amount of change are Open-Endedness and Material Environment. Again, students would like open-ended activities to be given to them 'sometimes' rather than 'seldom', and they would prefer to work in a better equipped chemistry laboratory 'often' and not only 'sometimes'.

Overall the present results for sex differences partially replicate previous research which has shown that female students tend to have a more favourable perception of their classroom environments than their male counterparts (Lawrenz, 1987; Giddings & Fraser, 1990; Fraser *et al.*, 1992b). In this present study, this is especially true for the actual form of the Integration scale, and for the preferred form of the Student Cohesiveness, Integration, Rule Clarity and Material Environment scales. The female students' perceptions were comparable to those of the male students for the actual form of the Student Cohesiveness, Rule Clarity and Material Environment scales. The only scale which produced results which did not replicate past research was the Open-Endedness scale. On both the actual and preferred forms of this scale, the female students had less favourable perceptions than the male students.

Associations between students' perceptions of their chemistry laboratory classroom environment and their chemistry-related attitudes

Three main methods of data analysis were used to investigate this environment-attitude relationship. They involved:
1. simple correlational analyses of relationships between individual attitudinal scales and individual environment scales,
2. multiple regression analyses of relationships between each attitudinal scale and the set of environment scales as a whole,
3. canonical analyses of relationships between the set of attitudinal scales and the set of environment scales.

The summary of results of these analyses are reported in Table 5.

The first type of analysis involved simple correlations between each environment scale and each attitude scale. The simple correlation values *(r)* are reported in Table 5. This table shows that the number of significant correlations ($p<0.05$) was 15 when the individual mean was used as the unit of analysis (i.e., about 20 times that expected by chance) and 10 for the analysis using the class mean as the unit of analysis (i.e., about 13 times that expected by chance). Generally, all five environment scales, Student Cohesiveness, Open-endedness, Integration, Rule Clarity and Material Environment, were significantly associated with each of the three attitude scales. In particular, Integration and Rule Clarity were strong and consistent correlates of the attitude scales for both units of analysis.

Furthermore, upon inspection of the signs for the values in Table 5, it can be seen that all the significant simple correlations were positive except for one case in which the greater levels of perceived Open-Endedness were associated with lower scores on Attitude to Scientific Inquiry in Chemistry for the analysis using the individual as the unit of analysis. A plausible explanation for this trend is that students might not favour open-ended activities in chemistry, and this might cause them to develop less favourable attitudes towards the subject. This line of reasoning is probably true in the Singapore context because, coming from a highly examination-oriented school system, students are used to structured activities and are comfortable with them as it helps them secure a pass grade in the examination.

TABLE 5

Simple (*r*), Multiple (*R*), and Canonical Correlations between Student Attitudes and Laboratory Classroom Environment for Two Units of Analysis

Attitude Scale	Unit of Analysis	Strength of Attitude-Environment Association										
		Student Cohesiveness		Open-Endedness		Integration		Rule Clarity		Material Environment		Multiple Correlation
		r	ß	*r*	ß	*r*	ß	*r*	ß	*r*	ß	*R*
Attitude to Scientific Inquiry in Chemistry	Individual	0.17**	0.10**	-0.06*	-0.05*	0.24**	0.18**	0.18**	0.09**	0.09**	-0.03	0.28**
	Class Mean	0.34**	0.18	-0.23	-0.20	0.39**	0.24	0.34*	0.16	0.17	-0.07	0.49*
Adoption of Scientific Attitudes in Chemistry	Individual	0.12**	0.07**	0.06*	0.07**	0.17**	0.13**	0.15**	0.09**	0.05*	-0.04	0.21**
	Class Mean	0.38**	0.20	0.15	0.19	0.55**	0.45**	0.38**	0.06	0.26	-0.02	0.61**
Enjoyment of Chemistry Lessons	Individual	0.17**	-0.01	0.14**	0.15**	0.37**	0.26**	0.32**	0.14**	0.32**	0.18**	0.47**
	Class Mean	0.22	-0.03	0.30**	0.32**	0.47**	0.18	0.62**	0.50**	0.37**	0.08	0.71**
Canonical Correlation	Individual						0.48**	0:20*				
	Class Mean						0.74**	0.45*				

r : simple correlation
ß : standardized regression coefficient for multiple correlation analysis
R : multiple correlation

* $p < 0.05$
** $p < 0.01$

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The second type of analysis consisted of a multiple correlation analysis performed separately for each of the three attitude scales with respect to the whole set of five environment scales, using both the individual student mean or the class mean as the unit of analysis. The multiple correlation analysis helps to reduce the Type I error rate associated with the simple correlational analysis. Hence, it gives a more parsimonious picture of the combined influence of correlated environment dimensions on attitudinal outcomes.

The multiple correlation *(R)* found between each of the attitudinal outcomes with the set of laboratory environment scales ranged from 0.21 to 0.47 when the individual mean was used as the unit of analysis, and from 0.49 to 0.71 when the class mean was used as the unit of analysis (Table 5). These values of R were significant ($p<0.05$) for all three attitudinal outcomes for both units of analysis. As expected, values were larger for analyses using the class means as the unit of analysis. This finding that outcome-environment relationships are larger when the class is used as the unit of analysis than when the individual student is used is consistent with a study carried out by Walberg (1972) and the meta-analysis conducted by Haertel, Walberg and Haertel (1981).

In order to determine which individual CLEI scales contributed most to explaining the variance in the attitudinal outcomes, an inspection of the standardised regression coefficients (ß) was made. These values are reported in Table 5.

Table 5 shows that the number of significant regression weights for the multiple correlation analysis was 12 using the individual as the unit of analysis, and 3 using the class mean as the unit of analysis. The results for the regression weights in the table indicates whether a specific laboratory environment scale makes a unique contribution to the variance in an attitude scale when scores on the other four laboratory environment scales are controlled.

On examination of the signs of the significant ß weights in Table 5, it can be seen that the regression weight is positive in most cases, with the exception of the Open-Endedness scale's negative association with Attitude to Scientific Inquiry in Chemistry when the individual mean was used as the unit of analysis. Furthermore, it is noted that the environment scales, Integration and Rule Clarity, are strong and consistent predictors of the three attitude scales. Hence, it appears that chemistry laboratory classes which integrate knowledge learnt from regular chemistry lessons, and provide clear rules for students to follow, have a positive effect on the students' chemistry-related attitudes. These findings are consistent with those obtained in the simple correlational analysis.

Multiple correlation analysis can help to overcome the problem of relationships among environmental scales, but not the relationships among the attitudinal outcome measures. As a result, an inflated Type I error rate could arise for the study as a whole. Canonical analyses can be used to provide a parsimonious picture of relationships existing between the set of correlated environment scales and the set of attitudinal outcomes.

The canonical analyses were conducted separately using the individual and the class as the unit of analysis. The results of the canonical analyses are shown at the bottom of Table 5. This table shows that two significant canonical correlations of 0.48 ($p<0.01$) and 0.20 ($p<0.05$) were found for the analysis involving the individual as the unit of analysis. With the class means as the unit of analysis, the two significant canonical correlations found were 0.74 ($p<0.01$) and 0.45 ($p<0.05$). In order to interpret the results of the canonical analyses, an examination was made of the magnitudes and signs of the structure coefficients (i.e., simple correlations between a canonical variable and its constituent variables) associated with each canonical variable. Within the limitations set by relatively small sample sizes for the canonical analyses involving class means (Stevens, 1986), the canonical correlation results obtained for analyses using the individual and class means were interpreted in similar ways.

The interpretation of the first canonical correlation was that classes with high levels of all five environment outcomes, particularly, Integration, Rule Clarity and Material Environment, promoted higher levels of all three attitudinal outcomes, especially, Enjoyment of Chemistry

Lessons. Once again, Rule Clarity and Integration were found to be strong and consistent predictors of the attitudinal outcomes, thus confirming the results obtained in the simple and multiple correlational analyses reported above. The interpretation of the second significant canonical correlation was that higher levels of Attitude to Scientific Inquiry in Chemistry were found in classes which had more Student Cohesiveness but less Open-Endedness. This seems to imply that students who held positive attitudes towards accepting scientific inquiry as a way of thought in Chemistry came from laboratory classes in which there was greater cooperation among students and where experiments were less open-ended. This finding for Open-Endedness replicates that of previous research conducted in Australia (McRobbie & Fraser, 1993) in that open-endedness can lead to less favourable science-related attitudes in students.

Comparison of the results of previous science laboratory environments studies with those of the present study

Finally, the results of the present study were compared with those of the original cross-national validation study conducted across six countries (Australia, the USA, Canada, England, Israel and Nigeria) and the Australian crossvalidation study. The areas compared included the student perceptions on all five SLEI dimensions, sex differences in perceptions of the science laboratory classroom environment, and the environment-attitude associations.

TABLE 6

Average Item Means of SLEI (Actual) Scores for each Scale for Upper Secondary School Students from Different Countries

Scale	Australia, 1875 upper secondary school students, 34-item version*	USA, 885 senior high school students, 34-item version*	Canada, 282 senior high school students, 34-item version*	Israel, 359 senior high school students, 34-item version*	Singapore, 1,592 Year 10 Chemistry students, 33-item version**
Student Cohesiveness	3.70	3.94	3.74	3.71	3.85
Open-Endedness	2.48	2.52	2.42	2.15	2.34
Integration	3.93	3.90	3.91	4.06	3.89
Rule Clarity	3.53	3.80	3.66	3.61	3.83
Material Environment	3.73	3.94	3.56	3.73	3.51

Adapted from Waldrip & Giddings (1993).

* Item 27 was not included in the SLEI then.

** Items 24 and 27 were omitted from the original 35-item version of SLEI.

First, the average item means obtained for each of the SLEI (Actual) scales for Singapore and several other countries for which data already exist were compared (see Table 6). An interesting point to note is that all of the other countries listed are western nations. No SLEI data have been reported for any Asian country as yet. The present Singapore study appears to be the first study carried out in an Asian country using the SLEI.

An examination of the data in Table 6 shows that Singapore's chemistry laboratory classes are characterised by lower levels of Integration and Material Environment, and greater levels of Rule Clarity than Australian, American, Canadian and Israeli science classes. Student Cohesiveness among Singaporean students also was at a higher level than that for Australian, Canadian and Israeli students. However, the level of Open-Endedness in the Singaporean chemistry laboratory class is relatively lower than that of the Australian, American and Canadian science classes. It is also interesting to note that the level of Open-Endedness, as compared to the levels of the other four environment dimensions, is lowest in all the countries listed in Table 6. This trend suggests a widespread closed-ended nature of laboratory classes around the world.

Second, sex differences in perceptions of science laboratory classroom environment were present for the Singapore sample as well as for the samples from the countries which participated in the cross-national validation study (Australia, the USA, Canada, England, Israel and Nigeria) (Giddings & Fraser, 1990; Fraser *et al.*, 1992b). In general, it was found that females perceived their environment more positively than males. However, for the Singapore sample only, males had more favourable perceptions of the Open-Endedness dimension than females.

Third, the associations between the nature of the chemistry laboratory classroom environment as perceived by the students and their chemistry-related attitudes found in past research in several countries (Australia, the USA, Canada, England, Israel and Nigeria) by Fraser *et al.* (1992b) and McRobbie and Fraser (1993) were replicated in the present study in Singapore. However, because the attitude instruments and the attitudinal outcomes were different among the studies, these findings could not be generalised.

CONCLUSION

This study set out to investigate the determinants and effects of perceptions of chemistry laboratory classroom environments in coeducational government secondary schools in Singapore. This study is distinctive because, in Singapore, there has been no research in the area of science classroom or science laboratory environments, nor any research which examines the environment-attitudinal outcomes linkage. Hence, this study marks the beginning of this field of research in science education in Singapore.

As part of the main study, the *Chemistry Laboratory Environment Inventory (CLEI)*, a slightly modified version of the *Science Laboratory Environment Inventory (SLEI)*, was crossvalidated for use with the Singapore sample. The results of the crossvalidation specifically in chemistry classes in Singapore replicated previous cross-national research involving the use of the SLEI in six other countries. For the Singaporean sample, each SLEI scale displayed satisfactory internal consistency, discriminant validity and factorial validity with either the individual or class mean as the unit of analysis. Also, each SLEI scale differentiated significantly between the perceptions of students in different classrooms.

A major objective of this study was to compare the chemistry laboratory classroom environment perceptions of teachers and students. It was found that teachers' perceptions were generally similar or more positive than those of their students on most of the CLEI dimensions. Also, preferred perceptions of both teachers and students were more favourable than their actual perceptions. For example, differences in actual and preferred perception scores ranged between effect sizes of 0.12 to 0.84 standard deviations for the students, and 0.70 to 1.90 standard deviations for the teachers. These findings were consistent with those reported for other classroom environment instruments in past research (e.g., Moos, 1979; Fraser, 1982).

Another aim of the present study was to investigate whether the stream and sex of the students were determinants of students' perceptions of their chemistry laboratory classroom environment. The results for stream showed that significant differences were found only between the preferred perception scores of the 'express' and the 'normal' stream students for three of the five CLEI dimensions, namely, Student Cohesiveness, Integration and Material Environment (effect sizes of 0.94 to 1.12 standard deviations). However, when the perception scores of male and female students were compared, they were found to differ in their actual perceptions of Integration and Open-Endedness (effect size of 0.50 standard deviations), and in their preferred perceptions for all five CLEI scales (effect sizes of 0.35 to 0.60 standard deviations). In most of these cases, female students were found to hold more favourable perceptions than male students, as was reported in previous research (Lawrenz, 1987; Giddings & Fraser, 1990; Fraser *et al.*, 1992b). However, unlike previous research, males in the present study perceived Open-Endedness more positively than the females, instead of the other way around.

In all of these comparisons, a recurrent finding which emerged was that students would like to see the greatest amount of change in the area of Open-Endedness and Material Environment. Generally, they seemed dissatisfied with the lack of open-ended activities in their chemistry laboratory classes. Neither were they happy with the present physical environment (adequacy of equipment and materials) of their chemistry laboratories.

All in all, it can be inferred that the student's sex and stream could affect to some extent his/her perceptions of his/her chemistry laboratory classroom environment. Hence, sex and stream are possible determinants of students' environment perceptions.

An investigation of the association between students' perceptions of their chemistry laboratory classroom environment and their chemistry-related attitudes was carried out. Two of the five environment scales, namely, Integration and Rule Clarity, were found to have a strong, consistent and positive relationship with all three attitudinal scales. However, Open-Endedness was found to be the only environment scale which consistently had a negative relationship with one of the attitude scales, namely, the Attitude to Scientific Inquiry in Chemistry scale. Thus, it seems that students' attitudes towards chemistry were enhanced in chemistry laboratory classes in which laboratory activities were integrated with the theory learnt in non-laboratory classes, and where rules for laboratory activities are given. On the other hand, students' attitudes to scientific inquiry seem to become less favourable in laboratory classes with more open-ended activities. These findings replicate previous research conducted in Australia using the SLEI and a different attitude instrument (McRobbie & Fraser, 1993).

Finally, the results of the present study were compared with those of previous studies conducted in Australia, the USA, Canada, England, Israel and Nigeria. It was found that Singapore's chemistry laboratory classes reflected lower levels of Integration and Material Environment, and higher levels of Rule Clarity, than Australian, American, Canadian and Israeli science classes. However, the level of Open-Endedness in the Singapore chemistry laboratory class is relatively lower than that of the Australian, American and Canadian science classes. In the area of sex differences, there were differences in perceptions of science laboratory classroom environments for both the Singaporean sample as well as for the samples from the other countries. Associations between students' perceptions of the nature of the science laboratory classroom environment and their attitudinal outcomes also existed for all samples in all the countries concerned, including Singapore.

It can be seen that many of the findings in this study helped substantiate those of past research involving the SLEI. However, there were some results which were perculiar to the Singaporean context. For example, none of the previous studies looked at stream differences, probably because the practice of streaming did not exist in their educational systems. But, it is a very important aspect in the Singapore educational system for it is argued that every child's potential would be maximised by the practice of streaming. Even though the results on stream differences might pertain to the Singapore context only, they still help enlarge the data set for the SLEI, thus enhancing its useability across nations, cultures and educational settings and systems.

It also is not surprising that the Singaporean chemistry laboratory classes were found to be more close-ended than those of several western countries, namely, Australia, the USA and Canada. The reason could stem from the highly centralised and prescriptive mode of education in existence in Singapore compared with the those of the other countries.

On the homefront, it is hoped that the findings of this study, the first in Singapore to focus on the unique learning environment of the chemistry laboratory class, will prove useful to Singapore chemistry teachers and possibly to science teachers in general. It serves to inform the teachers about how their students currently perceive their laboratory classes and what they would prefer them to be like. With this knowledge, these teachers are likely to be in a better position to make improvements in their laboratory classrooms so as to help their students foster more positive attitudes towards the subject and in turn help create a more supportive environment for teaching and learning. This is especially crucial for students in their final year of secondary school in a highly competitive education system like Singapore's.

Finally, below are some of the desirable ongoing and new directions of laboratory classroom environment research identified by Fraser (in press) that could prove worthwhile for science educators to pursue:

- Person-environment fit research to investigate whether students achieve better, cognitively and affectively, when there is a better match between their actual and preferred laboratory classroom learning environments. An example of such a study in science education using the *Individualised Classroom Environment Questionnaire (ICEQ)* was reported by Fraser and Fisher (1983a).
- Using qualitative methods to complement and substantiate findings from the use of quantitative methods in the present study of science laboratory classroom environments (e.g., Fraser & Tobin, 1989; Tobin & Fraser, 1989; Tobin, Kahle & Fraser, 1990).
- Combining the use of classroom and school environment measures within the same study (e.g., Fraser & Rentoul, 1982; Fraser, Williamson & Tobin, 1987).
- Incorporating classroom and laboratory classroom environment ideas into teacher education programs, the work of school psychologists, and teacher assessment schemes. In fact, Fisher and Fraser (1991) reported some case studies of how classroom environment work has been successfully incorporated into preservice and inservice education programmes. Their examples include using findings from classroom environment work to sensitize teachers to the subtle but important aspects of classroom life, and to help teachers in their overall evaluation and monitoring duties. It also was reported that information on students' perceptions of the classroom learning environment provided a valuable source of feedback about teaching performance for the formative and summative evaluation of trainee teachers, and helped complement feedback provided by the trainee's school-based cooperating teachers and university supervisors.

REFERENCES

Anderson, G.J., & Walberg, H.J. (1974). Learning environments. In H.J. Walberg (Ed.), *Evaluating educational performance: A sourcebook of methods, instruments, and examples.* Berkeley, California: McCutchan.

Chavez, R.C. (1984). The use of high inference measures to study classroom climates: A review. *Review of Educational Research, 54,* 237-261.

DeCarlo, C.L., & Rubba, P.A. (1991). *What happens during high school chemistry laboratory sessions?* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Fontane, WI.

Fisher, D.L., & Fraser. B.J. (1991). Incorporating classroom environment ideas into teacher education: An Australian perspective. Paper presented at annual meeting of American Educational Research Association, Chicago, IL.

Fraser, B.J. (1980). Guest editor's introduction: Classroom environment research in the 1970's and 1980's. *Studies in Educational Evaluation, 6,* 221-223.

Fraser, B.J. (1981). *Test of Science-Related Attitudes (TOSRA).* Melbourne: Australian Council for Educational Research.

Fraser, B.J. (1982). Differences between student and teacher perceptions of actual and preferred classroom learning environment. *Educational Evaluation and Policy Analysis, 4,* 511-519.

Fraser, B.J. (1986a). *Classroom environment.* London: Croom Helm.

Fraser, B.J. (Ed.) (1986b). *The study of learning environments* (Volume 1). Salem, Oregon: Assessment Research.

Fraser, B.J. (Ed.) (1987). *The study of learning environments* (Volume 2). Perth: Curtin University of Technology.

Fraser, B.J. (Ed.) (1988). *The study of learning environments* (Volume 3). Perth: Curtin University of Technology.

Fraser, B.J. (1989). Twenty years of classroom climate work: Progress and prospect. *Journal of Curriculum Studies, 21,* 307-327.

Fraser, B.J. (in press). Classroom and school climate. In D. Gabel (Ed.), *Handbook of Research on Science Teaching and Learning.* New York: Macmillan.

Fraser, B.J., Giddings, G., & McRobbie, C. (1992a). Assessment of the psychosocial environment of university science laboratory classrooms: A cross-national study. *Higher Education, 24,* 431-451.

Fraser, B.J., Giddings, G., & McRobbie, C.J. (1992b). *Science laboratory classroom environments: A cross-national study.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Boston, MA.

Fraser, B.J., McRobbie, C., & Giddings, G. (1993). Development and cross-national validation of a laboratory classroom environment instrument for senior high school science. *Science Education, 77,* 1-24.

Fraser, B.J., & Rentoul, A.J. (1982). Relationships between school-level and classroom-level environment. *Alberta Journal of Educational Research, 28,* 212-225.

Fraser, B.J., & Tobin, K. (1989). Student perceptions of psychosocial environments in classrooms of exemplary science teachers. *International Journal of Science Education, 11,* 19-34.

Fraser, B.J., & Walberg, H.J. (Eds.) (1991). *Educational environments: Evaluation, antecedents and consequences.* Oxford, England: Pergamon Press.

Fraser, B.J., Williamson, J.C., & Tobin, K. (1987). Use of classroom and school climate scales in evaluating alternative schools. *Teaching and Teacher Education, 3,* 219-231.

Giddings, G.J., & Fraser, B.J. (1990). *Cross-national development, validation and use of an instrument for assessing the environment of science laboratory classes.* Paper presented at the annual meeting of the American Educational Research Association, Boston.

Hofstein, A., & Lunetta, V.N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research, 52,* 201-217.

Lawrenz, F. (1987). Gender effects for student perception of the classroom psychosocial environment. *Journal of Research in Science Teaching, 24,* 689-697.

Lehman, J.R. (1989). Chemistry teachers' and chemistry students' perceived advantages and disadvantages of high school chemistry laboratories. *School Science and Mathematics, 89,* 510-514.
McRobbie, C., & Fraser, B.J. (1993). Associations between student outcomes and psychosocial environment in science laboratory classes. *Journal of Educational Research, 87,* 78-85.
Moos, R.H. (1968). The assessment of the social climates of correctional institutions. *Journal of Research in Crime and Delinquency, 5,* 174-188.
Moos, R.H. (1979). *Evaluating educational environments: Procedures, measures, findings and policy implications.* San Francisco: Jossey-Bass.
Moos, R.H., & Houts, P.S. (1968). The assessment of the social atmospheres of psychiatric wards. *Journal of Abnormal Psychology, 73,* 595-604.
Moos, R.H., & Spinrad, S. (1984). *The social climate scales: Annotated bibliography 1979-1983.* Palo Alto, California: Consulting Psychologists Press.
Moos, R.H., & Trickett, E.J. (1974). *Classroom Environment Scale Manual* (1st. ed.). Palo Alto, California: Consulting Psychologists Press.
Moos, R.H., & Trickett, E.J. (1987). *Classroom Environment Scale Manual* (2nd. ed.). Palo Alto, California: Consulting Psychologists Press.
Tan, Keng Yam (1990). Foreward. In John Yip & W.K. Sim. (Eds.), *Evolution of educational excellence: 25 Years of education in the Republic of Singapore.* Singapore: Longman.
Teh, G., & Fraser, B.J. (1993). *A study of computer assisted learning environments in Singapore.* Paper presented at annual meeting of American Educational Research Association, Atlanta, GA.
Tobin, K., & Fraser. B.J. (1989). Barriers to higher-level cognitive learning in high school science. *Science Education, 73,* 659-682.
Tobin, K., Kahle, J.B., & Fraser, B.J. (Eds.) (1990). *Windows into science classes: Problems associated with higher-level cognitive learning.* London: Falmer Press.
Toh, K.A. (1993). A review of studies in science education in Singapore : 1971-1990. *Singapore Journal of Education, 30,* 50-60.
Walberg, H.J. (Ed.) (1979). *Educational environments and effects: Evaluation, policy, and productivity.* Berkeley, California: McCutchan.
Waldrip, B.B., & Giddings, G.J. (1993). *Culture, pedagogy and productivity.* Paper presented at annual conference of Australian Association for Research in Education, Freemantle, Australia.
Stevens, J. (1986). Applied multivariate statistics for the social sciences. Hillsdale, NJ: Lawrence Erlbaum.

APPENDIX A

Factor Loadings for CLEI (Student/Actual) using Individual Student Scores as the Unit of Analysis

Item Number	Student Cohesiveness	Open-Endedness	Integration	Rule Clarity	Material Environment
1	0.67				
6	0.54				
11	0.61				
16	0.73				
21	0.49				
26	0.48				
31	0.37			0.38	
2				0.33	
7		0.42			
12		0.43			
17		0.57			
22		0.60			
32					
3			0.56		
8			0.62		
13			0.31		
18			0.47		
23			0.65		
28			0.43	0.50	
33			0.68		
4				0.61	
9					
14				0.66	
19				0.57	
29				0.63	
34				0.37	
5					0.56
10					0.40
15					0.66
20					0.68
25					0.63
30					0.55
35					0.57
% Variance	5.4	3.9	5.4	16.2	6.3
Eigen value	1.89	1.35	1.87	5.65	2.20

The sample size was 1,592 upper secondary chemistry students in 56 classes from 28 schools.

Only 33 items were involved in the factor analysis. Items 24 and 27 were omitted because of inconsistent results obtained in the item analysis.

Factor loadings smaller than 0.30 have been omitted for these analyses involving the individual as the unit of analysis.

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