<table>
<thead>
<tr>
<th>Title</th>
<th>Science laboratory classroom environments in secondary chemistry classes in Singapore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Angela Wong F. L. &amp; Barry J. Fraser</td>
</tr>
<tr>
<td>Source</td>
<td>Australian Association for Research in Education Conference, Tasmania, Australia, 26 November to 30 November 1995</td>
</tr>
</tbody>
</table>

This document may be used for private study or research purpose only. This document or any part of it may not be duplicated and/or distributed without permission of the copyright owner.

The Singapore Copyright Act applies to the use of this document.
SCIENCE LABORATORY CLASSROOM ENVIRONMENTS
IN SECONDARY CHEMISTRY CLASSES IN SINGAPORE

Angela Wong F. L.
&
Barry J. Fraser

Paper presented at the Annual Conference of the Australian Association for Research in Education, held in Hobart, Tasmania, on 26-30 Nov 1995
Science Laboratory Classroom Environments in Secondary Chemistry Classes in Singapore

Angela F. L. Wong
National Institute of Education
Nanyang Technological University
469 Bukit Timah Road
Singapore 259756
Republic of Singapore

Barry J. Fraser
Science and Mathematics Education Centre
Curtin University of Technology
GPO Box U1987
Perth, Western Australia 6001
Australia

ABSTRACT

This study in science laboratory classroom environment is distinctive in that it was the first of such studies to use multilevel analysis as a method of data analysis to study the effects of classroom environment dimensions, and a first to examine the differences in perceptions between students of different abilities. The primary aim was to examine the relationships between students' attitudes towards chemistry and their perceived laboratory environments as assessed by a modified version of the Science Laboratory Environment Inventory. Another purpose was to explore the differences in perceptions between teachers and students, boys and girls, and higher and average ability students. The sample consisted of 1,592 final year secondary school (i.e., Year 10) students studying chemistry and their chemistry teachers in 56 classes from 28 randomly selected coeducational government schools of similar standard in Singapore.

The investigation of attitude-environment associations involved using simple, multiple and canonical correlational analyses, and multilevel analysis. For the purpose of exploring differences in perceptions between the different groups, multivariate analyses of variance (MANOVA) for repeated measures were performed with the relevant variables.

The findings revealed the existence of positive associations between the nature of the chemistry laboratory classroom environment and the students' attitudinal outcomes. In addition, it was found that perceptions of students and teachers differed; that girls held more favourable perceptions than boys; and the students of different abilities differed only in their preferred perceptions.

Key words: Learning/classroom environment, science education.

INTRODUCTION

Although classroom environment research has spanned a period of more than 20 years (Fraser, 1994; Fraser & Walberg, 1991), research specifically in science laboratory classroom environment still is in its infancy. Recently the development of the Science Laboratory Environment Inventory (SLEI) (Fraser et al., 1992, 1993) has facilitated the expansion of research in this area. 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, 1993; Henderson, Fisher & Fraser, 1994). In a previous cross-national study involving six countries (Australia, the USA, Canada, England, Israel and Nigeria), Fraser et al. (1992) 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.

Many previous studies of environment-outcome associations have analysed data using ordinary least squares or multiple regression techniques. These techniques do not take into account the hierarchical structure of the data, i.e., the student level and the class level. Hence, the Hierarchical Linear Model (HLM) or multilevel analysis which provides the best theoretical basis for separating student and class level variables was used in this study to take into consideration this multilevel data (Bryk & Raudenbush, 1992).

In the cross-national study mentioned above, 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.

In the Singapore context, science education research for the past 20 years as reviewed by Toh (1993) comprised studies ranging 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, science classroom environment research has been almost non-existent in Singapore except for a recent study by Yap (1994). Thus, this study of chemistry laboratory classes is an attempt to expand 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 examine the relationships between students' attitudes towards chemistry and their perceived laboratory environment.
2. To explore the differences in perceptions of chemistry laboratory environments between
   - teachers and students,
   - boys and girls, and
   - higher and average ability students.

SAMPLE

The sample consisted of 1,592 final year secondary school (i.e., tenth grade) chemistry students of higher and average abilities, and their chemistry teachers. Fifty-six (56) classes from 28 randomly selected coeducational government schools of similar standard in Singapore were selected. From every school, one higher ability and one average ability 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 questionnaire, 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 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 Science Laboratory Environment Inventory (SLEI). 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, 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 higher ability and 28 secondary 5 average ability classes 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. Approximately one hour was required to administer all questionnaires to each class.
METHOD & RESULTS

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 multiple regression analyses and multilevel analysis. The multiple regression analysis was 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. However, the use of the student as the unit of analysis assumes that students in the same class respond independently of each other. This is an inaccurate assumption because students in the same class are 'nested' within classes, so their responses within classes are class dependent. This is especially true for the sample used in this study. Intact classes were used because it would have been too disruptive to the school curriculum to select students at random. This would have meant taking students out of their classes for questionnaire administration and, in the Singapore context, this would have been impractical. Because the student sample consisted of intact classes, the individual students within these classes would be more similar than if a random sample of students had been taken. Such data have a hierarchical structure (i.e., data at the student level and data at the class level). Multilevel analysis which takes into account this 'nesting' of students within classes, now is being used to handle data with a hierarchical structure. The HLM is such a strategy. More details of how this strategy was used to analyse the data in this study is provided in Wong (1994). The results obtained from the two analyses were compared to examine similarities and differences. These results are given in Table 1.

Table 1 shows that 12 significant attitude-environment associations emerged for the multiple regression analysis using the individual as the unit of analysis, and 3 significant associations were obtained using the class mean as the unit of analysis. For the HLM results, 12 cases of significant attitude-environment associations were recorded. Out of these, 10 were at the student (individual) level and two were at the class level of analysis.

In the multiple regression analysis, Integration was 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. 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).

On the whole, the HLM results supported those of the multiple regression analysis. It was found again that Integration was a strong and consistent predictor of all three attitudinal outcomes at the student level. Student Cohesiveness, Open-Endedness and Rule Clarity were found to be strong predictors of two of the attitudinal outcomes at the student level. Open-Endedness and Rule Clarity also were significantly associated with Enjoyment of Chemistry Lessons at the class level of analysis.
Table 1: Comparison of the Strength of the Attitude-Environment Association using Multiple Regression Analysis and Hierarchical Linear Model Analysis

<table>
<thead>
<tr>
<th>Attitude Scale</th>
<th>Level of Analysis</th>
<th>Standardised Regression Coefficient ($\beta$) for Attitude-Environment Association</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Student Cohesiveness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HLM</td>
</tr>
<tr>
<td>Attitude to Scientific Inquiry in Chemistry</td>
<td>Individual/Student Class</td>
<td>0.13**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Adoption of Scientific Attitudes in Chemistry</td>
<td>Individual/Student Class</td>
<td>0.05*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.11</td>
</tr>
<tr>
<td>Enjoyment of Chemistry Lessons</td>
<td>Individual/Student Class</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.07</td>
</tr>
</tbody>
</table>

MR : multiple regression analyses  
HLM: hierarchical linear model (HLM) analyses

* $p < 0.05$  
** $p < 0.01$
However, the HLM did not support the finding from the multiple regression analysis that Open-Endedness was significantly negatively associated with the Attitude to Scientific Inquiry in Chemistry. Material Environment was found to be significantly associated only with the attitudinal outcome, Enjoyment of Chemistry Lessons, and only at the student level of analysis. Hence, from the HLM analysis, it appears that chemistry laboratory classes which integrate knowledge learnt from regular chemistry theory classes have a positive effect on students’ chemistry-related attitudes. This finding is consistent with that obtained in the multiple regression analysis.

Comparison of chemistry laboratory classroom environment perceptions of teachers and students

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.

Table 2: Scale Means and Standard Deviations for Actual and Preferred Versions of the CLEI for Students and Teachers

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of Items</th>
<th>Form</th>
<th>Scale Mean</th>
<th>Standard Deviation</th>
<th>Item Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Student</td>
<td>Teacher</td>
<td>Student</td>
</tr>
<tr>
<td>Student Cohesiveness</td>
<td>7</td>
<td>Actual</td>
<td>26.96</td>
<td>26.88</td>
<td>4.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>28.38</td>
<td>30.38</td>
<td>4.24</td>
</tr>
<tr>
<td>Open-Endedness</td>
<td>6</td>
<td>Actual</td>
<td>14.04</td>
<td>11.66</td>
<td>3.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>17.15</td>
<td>18.36</td>
<td>4.30</td>
</tr>
<tr>
<td>Integration</td>
<td>7</td>
<td>Actual</td>
<td>27.26</td>
<td>27.45</td>
<td>4.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>27.70</td>
<td>30.43</td>
<td>4.47</td>
</tr>
<tr>
<td>Rule Clarity</td>
<td>6</td>
<td>Actual</td>
<td>22.99</td>
<td>25.79</td>
<td>3.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>23.42</td>
<td>26.54</td>
<td>3.59</td>
</tr>
<tr>
<td>Material Environment</td>
<td>7</td>
<td>Actual</td>
<td>24.55</td>
<td>25.73</td>
<td>4.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>28.47</td>
<td>32.27</td>
<td>5.40</td>
</tr>
</tbody>
</table>

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 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 actual and preferred perceptions between teachers and students were compared using the classroom environment profiles shown in Figure 1. The first step in the construction of these profiles 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.

The 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 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 item mean scores. The item means were plotted instead of the scale means because of the difference in the number of items in the five scales. Hence the 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 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. 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 item means given in Table 2.

Comparison of chemistry laboratory classroom environment perceptions of boys and girls, and ‘higher ability’ and ‘average ability’ students

When comparing the perceptions of the chemistry laboratory classroom environment of boys and girls, and students of higher and average abilities, 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 ability and the repeated measures independent variable was sex. This analysis confirmed that significant differences existed overall between the sexes and the two ability groups. It also showed that there was no significant interaction between sex and ability. 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 could arise from numerous individual significance tests being conducted. The 10 two-way ANOVAs yielded significant differences between sex in seven cases and between abilities for three cases.

Table 3: Scale Means and Standard Deviations for the Actual and Preferred Versions of the CLEI for Boys and Girls

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of Items</th>
<th>Form</th>
<th>Scale Mean</th>
<th>Standard Deviation</th>
<th>Item Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Actual</td>
<td>Boy</td>
<td>Girl</td>
<td>Difference</td>
</tr>
<tr>
<td>Student Cohesiveness</td>
<td>7</td>
<td>Actual</td>
<td>26.87</td>
<td>27.15</td>
<td>-0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>28.14</td>
<td>28.70</td>
<td>-0.56*</td>
</tr>
<tr>
<td>Open-Endedness</td>
<td>6</td>
<td>Actual</td>
<td>14.25</td>
<td>13.73</td>
<td>0.52**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>17.50</td>
<td>16.83</td>
<td>0.67**</td>
</tr>
<tr>
<td>Integration</td>
<td>7</td>
<td>Actual</td>
<td>27.01</td>
<td>27.77</td>
<td>-0.76**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>27.27</td>
<td>28.28</td>
<td>-1.01**</td>
</tr>
<tr>
<td>Rule Clarity</td>
<td>6</td>
<td>Actual</td>
<td>26.27</td>
<td>26.48</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>26.36</td>
<td>27.19</td>
<td>-0.83**</td>
</tr>
<tr>
<td>Material Environment</td>
<td>7</td>
<td>Actual</td>
<td>24.47</td>
<td>24.95</td>
<td>-0.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>27.85</td>
<td>29.30</td>
<td>-1.45**</td>
</tr>
</tbody>
</table>

* 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.

Item Means were calculated by dividing the means 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 scale means and standard deviations for the actual and preferred perception scores calculated across the 50 coeducational classes for the boys' and girls' perception scores for each of the five CLEI scales are tabulated in Table 3. Similarly, Table 4 contains the same statistics calculated across 28 'higher ability' and 28 'average ability' classes (i.e., total sample of 56 classes) on the actual and preferred versions of CLEI.

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 a simplified plot of the results in Table 3, while Figure 3 is the plot for Table 4. The response alternatives of the CLEI instrument corresponding to the value intervals on the item mean axis in both of these figures are as follows: 1 = 'Never', 2 = 'Seldom', 3 = 'Sometimes', 4 = 'Often', 5 = 'Very Often'.

An examination of Table 3 and Figure 2 shows that boys and girls differed significantly ($p<0.01$) in actual perceptions for two of the five CLEI scales, namely, Integration and Open-Endedness. Both boys and girls agreed that Integration was 'often' practised, but they 'seldom' had open-ended activities in their present laboratory classes. However, girls perceived that Integration was practised more frequently than was perceived by boys. In the area of Open-Endedness, the boys perceived its occurrence more frequently than the girls. Each of these differences had an effect size of about 0.50. For the remaining three scales, Student Cohesiveness, Rule Clarity and Material Environment, there was no significant difference between the perceptions of the boys and girls. 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.

Furthermore, Figure 2 shows that the differences in preferred perception scores between boys and girls differed significantly ($p<0.05$) for all five CLEI scales. Girls had higher levels of preferences than boys in four of the five CLEI scales, namely, Student Cohesiveness,
Integration, Rule Clarity and Material Environment. These differences 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 girls. This could indicate that girls 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 boys. However, in the area of Open-Endedness, an effect size of 0.39 in favour of the boys was found.

Another interesting feature illustrated in Figure 2 was that the two areas in which both boys and girls would like to see the greatest amount of change are Open-Endedness and Material Environment. 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 girls tend to have a more favourable perception of their classroom environments than boys (Lawrenz, 1987; Giddings & Fraser, 1990; Fraser et al., 1992).

When the results of the two ability groups were compared, it was found that they differed only in their preferred perceptions. The reason for this similarity in actual perceptions held by students from both ability groups could be that the teachers tend to treat these final year classes, whether they are in the higher ability class or the average ability class, rather similarly because they both were being prepared for the same national examination at the end of the school year. The teachers probably felt that, by so doing, neither group would feel disadvantaged.

Table 4: Scale Means and Standard Deviations for the Actual and Preferred Versions of the CLEI for Higher Ability and Average Ability Students

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of Items</th>
<th>Form</th>
<th>Scale Mean Higher</th>
<th>Scale Mean Average</th>
<th>Standard Deviation Higher</th>
<th>Standard Deviation Average</th>
<th>Item Mean Higher</th>
<th>Item Mean Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student Cohesiveness</strong></td>
<td>7</td>
<td>Actual</td>
<td>27.26</td>
<td>27.00</td>
<td>0.26</td>
<td>1.25</td>
<td>1.33</td>
<td>3.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>29.13</td>
<td>27.77</td>
<td>1.36**</td>
<td>1.14</td>
<td>1.29</td>
<td>4.16</td>
</tr>
<tr>
<td><strong>Open-Endedness</strong></td>
<td>6</td>
<td>Actual</td>
<td>13.92</td>
<td>14.12</td>
<td>-0.20</td>
<td>0.89</td>
<td>0.84</td>
<td>2.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>17.38</td>
<td>16.83</td>
<td>0.55</td>
<td>1.26</td>
<td>1.36</td>
<td>2.90</td>
</tr>
<tr>
<td><strong>Integration</strong></td>
<td>7</td>
<td>Actual</td>
<td>27.85</td>
<td>26.83</td>
<td>1.02</td>
<td>1.57</td>
<td>1.46</td>
<td>3.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>28.40</td>
<td>27.06</td>
<td>1.34**</td>
<td>1.30</td>
<td>1.56</td>
<td>4.06</td>
</tr>
<tr>
<td><strong>Rule Clarity</strong></td>
<td>6</td>
<td>Actual</td>
<td>23.94</td>
<td>22.94</td>
<td>0.10</td>
<td>1.57</td>
<td>1.30</td>
<td>3.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>23.68</td>
<td>23.16</td>
<td>0.52</td>
<td>1.16</td>
<td>1.31</td>
<td>3.95</td>
</tr>
<tr>
<td><strong>Material Environment</strong></td>
<td>7</td>
<td>Actual</td>
<td>24.72</td>
<td>24.60</td>
<td>0.12</td>
<td>1.92</td>
<td>2.01</td>
<td>3.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preferred</td>
<td>29.47</td>
<td>27.54</td>
<td>1.93**</td>
<td>1.97</td>
<td>2.04</td>
<td>4.21</td>
</tr>
</tbody>
</table>

** p<0.01

The sample consisted of 1,592 students in 56 classes from 28 schools. Of these, there were 803 students from 28 higher ability classes and 789 students from 28 average ability classes.

Item Means were calculated by dividing the means 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 ability groups are compared, it can be seen clearly from both Table 4 and Figure 3 that there were significant differences between their mean scores for all the CLEI scales except Open-Endedness and Rule Clarity. Relative to the average group, the higher ability group preferred more Student Cohesiveness, 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 groups were similar.

Figure 3: Simplified Plot of Significant Differences between Higher Ability and Average Ability Students' Actual and Preferred Perception Scores

Environment Scale

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

Once again, as noted previously when discussing sex differences, the two areas in which students from both ability groups would like to see the most change are Open-Endedness and Material Environment. This is clearly illustrated in Figure 3. The students 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'.

CONCLUSION

This study set out to investigate the relationships between students' attitudes towards chemistry and their perceived laboratory environment. Multiple regression analysis was used to investigate this association. In addition, multilevel analysis was used to confirm the results.

The multiple regression analysis yielded results which replicated past research (McRobbie & Fraser, 1993) in that there were statistically significant associations between the nature of the laboratory classroom environment and students' attitudinal outcomes. The most striking
findings were that Integration and Rule Clarity were strong and consistent predictors of the attitude outcomes. This implied that students' attitudes towards chemistry are likely to be enhanced in chemistry laboratory classes where laboratory activities are linked with the theory learnt in non-laboratory classes and where clear rules are provided.

Overall, the HLM also gave results largely similar to those of the multiple regression analysis. Out of the 15 statistically significant attitude-environment associations found in the multiple regression analysis, 12 were replicated in the multilevel analysis. Once again, the Integration dimension was found to be a strong and consistent predictor of the three outcomes at the student level.

It is obvious that there is a relationship between the nature of the laboratory environment and the attitudinal outcomes of students. However, it cannot be concluded in absolute terms that the nature of the environment caused the observed student attitudinal outcomes. In order for such a conclusion to be attempted, classroom intervention studies would have to be conducted.

Another major objective of this study was to compare the chemistry laboratory classroom environment perceptions of teachers and students, boys and girls, and students of different ability groups. 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. These findings were consistent with those reported for other classroom environment instruments in past research (e.g., Moos, 1979; Fraser, 1982).

When the perception scores of boys and girls were compared, they were found to differ in their actual perceptions of Integration and Open-Endedness and in their preferred perceptions for all five CLEI scales. In most of these cases, girls were found to hold more favourable perceptions than boys, as was reported in previous research (Lawrenz, 1987; Giddings & Fraser, 1990; Fraser et al., 1992). However, unlike previous research, boys in the present study perceived Open-Endedness more positively than the girls, instead of the other way around. The results for different ability groupings showed that significant differences were found only between the preferred perception scores of the higher ability and the average ability students for three of the five CLEI dimensions, namely, Student Cohesiveness, Integration and Material Environment.

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.

It can be seen that the findings of this study helped substantiate those of past research involving the SLEI. However, there were some results which were peculiar to the Singaporean context. For example, none of the previous studies looked at ability differences, probably because the practice of streaming students to different classes according to their academic abilities 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 ability differences might
pertain to the Singapore context only, they still help enlarge the data set for the SLEI, thus enhancing its usability across nations, cultures and educational settings and systems.

On the homefront, it is hoped that the findings of this study, 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.

REFERENCES


AW/BF/AARE95 14


