Gender Differences in Perceptions of Chemistry Laboratory Environments in Singapore

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It is important to take into account gender differences within a classroom setting. This is to ensure that the needs of both the boys and the girls are catered for. In this study, the differences in boys' and girls' perceptions of their chemistry laboratory classroom environment are examined using the Science Laboratory Environment Inventory (SLEI). The sample comprised 649 boys and 801 girls in 50 upper secondary coeducational science classes from 28 schools in Singapore. The students responded to the actual and preferred versions of the SLEI, and their responses were compared. The findings showed that the girls perceived the learning environment of their chemistry laboratory classes more favourably than the boys. These differences in perceptions are presented and some implications for chemistry laboratory classrooms discussed.

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Introduction

Sex-environment associations using classroom inventories has not been extensively investigated as yet. In studies that have been carried out in this area, researchers found that boys preferred a more competitive learning environment while girls were more comfortable with a more personal and cooperative type of learning environment (Owens & Straton, 1980; Byrne, Hattie & Fraser, 1986). In the more specific area of science laboratory classroom environment, Fraser, Giddings and McRobbie (1995) investigated sex differences in the perceptions of laboratory environments among 258 secondary students in 29 classes in Australia. They found that females perceived their learning environment more favourably than did males.

Lawrenz (1987) also showed that the difference in perceptions of classroom environment by male and female students could be due to the sex of the teacher taking the class. She reported that these gender-related differences in student perceptions became more pronounced as students got older. At the fourth grade level, male and female students perceived no differences in the environments of classes taught by teachers of either sex. At the seventh grade, male and female students continued to have similar impressions of their classes except that they perceived classes taught by female teachers as having more friction than classes taught by male teachers. By the time one gets to the secondary level, male and female students perceived their classes differently from each other irrespective of the teacher's sex.

Another aspect of classroom environment that has been examined is teacher-student interactions. The amount of interaction between the teacher and the student and the amount of participation/involvement accorded to him/her by the teacher also affects his/her learning outcome. Past research showed that boys tend to be spoken to more often than girls, are asked more higher-order questions, and generally dominate every type of teacher-student interaction including receiving significantly more praise and criticism (Becker, 1981; Hall, 1982; Sadker & Sadker, 1985; Jones & Wheatley, 1989, 1990). In his research

on classroom interactions, Tobin (1990) also found that target students (i.e., students who dominate interactions with the teacher in whole-class activities, small-group discussions and laboratory activities) were more frequently males rather than females.

In the area of science laboratory environments, Tobin and Garnett (1987) examined the gender-related differences in participation in secondary school science activities. The data from observations of 15 science teachers revealed that male students participated to a larger extent than the females in public interactions with the teacher and in the data collecting segments of laboratory activities. Similar findings showing that male students dominated every type of teacher-student interaction in laboratory work were reported by Jones and Wheatley (1989, 1990).

The conclusions from the above studies suggest that the classroom environment affects male and female students differently. This further implies that, if the environment could be adjusted or modified to make it more equitable to both sexes, then there would be a good chance of reducing sex differences in affective outcomes. This actually has been suggested by Linn and Hyde (1989) who claim that "the magnitude of sex difference is clearly a function of context or situation" (p. 26). Hence, they suggested that environments that encourage and reward the cooperative behaviour of students and instil their confidence should be harnessed to minimise sex differences.

A review of the chemistry education research scene in Singapore has revealed that research in this field mainly has comprised investigations into the learning difficulties of students in the subject, issues of sex differences in chemistry achievement and attitudes, and practical work. Thus, there is scope for research in the field of learning environment, both in the chemistry classroom and the chemistry laboratory classroom. Such studies would serve to inform chemistry teachers in Singapore about how their students actually perceive their classrooms/ laboratories as well as what they would prefer them to be like. In this way, teachers are likely to be able to make the necessary changes to their classrooms/laboratories so as to foster more positive attitudes towards the subject and a more supportive environment for learning. In addition, teachers also are likely be able to handle classroom/laboratory procedures more fairly, giving both male and female students equal opportunities for participation.

This study was embarked upon with the view of providing a chemistry laboratory environment which is more equitable to both sexes. Based on

the research findings discussed above and on the authors' own experiences in teaching chemistry, it would seem that female students and male students are treated differently, especially in laboratory classes. Teachers tend to help the former in their laboratory experiments more than they would help the latter. Is that why it has been found in western studies that the female students have been found to perceive their learning environment more favourably than male students (Lawrenz, 1987; Fraser et al., 1992b)? Is this trend also true for Singapore? If so, what can chemistry teachers in Singapore do to minimise these differences so as to provide both the male and female students a fairer environment to work in? This issue was investigated in this study.

Methodology

Sample

The sample consisted of 649 male and 801 female final year secondary school (i.e., tenth grade) chemistry students from 50 intact classes (average class enrolment of 28 to 29 students) from 28 randomly-selected coeducational government schools of similar standard in Singapore. Intact classes were used because it would have been too disruptive to the curriculum and too time-consuming to take students out of their classes for the questionnaire administration. In these classes, chemistry was taught as one half of a subject called 'Science'. The other half of the subject is physics.

Instruments

The chemistry laboratory classroom environment perceptions of the students were measured using a modified version of the Science Laboratory Environment Inventory (SLEI) designed by Fraser, McRobbie and Giddings (1993). This modified version was renamed Chemistry Laboratory Environment Inventory (CLEI) in the present study.

The SLEI comes in two versions - the actual and the preferred - just like other learning environment instruments. Hence, not only are the students' perceptions of their actual learning environment assessed, but also the students' perceptions of their ideal (preferred) learning environment are measured.

Furthermore, a noteworthy feature of the SLEI is that it 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 student's perception of his/her own role in the laboratory class. It is hoped that the development of the Personal form, the first of its kind for a classroom environment instrument, will allow for "more meaningful and sensitive investigations of the subenvironments existing within a class for different subgroups of students, as well as for constructing more meaningful case studies of individual students" (Fraser, Giddings and McRobbie, 1995, p. 414).

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 Science Laboratory Environment Inventory (SLEI) designed by Fraser, Giddings and McRobbie (1995). 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 modified instrument was called the Chemistry Laboratory Environment Inventory (CLEI) and the actual and preferred versions of the Personal form were retitled the Student Actual Form and the Student Preferred Form, respectively. The modification of the instrument only entailed replacing the word `science' with `chemistry' throughout. The rest of the wording of items remained unchanged.

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. However, following the item analysis reported elsewhere (Wong & Fraser, 1995), 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. Out of the 35 items, 13 of them are worded and scored in the reverse manner. A description of the five scales for the CLEI and an example of an item in each of them is given in Table 1.

The sample items referred to in Table 1 are from the actual version of the Student form of the CLEI (i.e., the modified version of the Personal form of the SLEI). In the preferred version, the wording of the items are almost identical except for the use of words like 'would'. For example, the item "The teacher outlines safety precautions to me before my chemistry laboratory sessions commence" in the actual version is reworded as "The teacher would outline safety precautions to me before my chemistry laboratory sessions commence" in the preferred version.

Procedures for Questionnaire Administration

The researcher administered the instruments to 50 classes of students in the 28 coeducational government secondary schools in Singapore within the first term of the school year (i.e., January-March). The students completed the two questionnaires, namely, the actual and preferred versions of the Student form of the CLEI. Approximately one hour was required to administer all the questionnaires to each class.

TABLE 1 : Description of CLEI Scales in the Student (Actual) Form

Scale Name Description Sample Item
Student Cohesiveness Extent to which students know, help and are supportive to one another. I get on well with students in my chemistry laboratory class. (+)
Open-Endedness

Extent to which the laboratory activities emphasise an open-ended, divergent approach to experimentation.

In my chemistry laboratory class, I am required to design my own experiments to solve a given problem. (+)

Integration

Extent to which the laboratory activities are integrated with non-laboratory and theory classes.

What I do in our regular chemistry class is unrelated to my laboratory work. (-)

Rule Clarity

Extent to which behaviour in the laboratory is guided by formal rules.

The teacher outlines safety precautions to me before my chemistry laboratory sessions commence. (+)

Material Environment

Extent to which the laboratory equipment and materials are adequate.

The chemistry laboratory equipment which I use is in poor working order. (-)

Adapted from Fraser, Giddings & McRobbie (1992).

Items designated (+) are scored 1, 2, 3, 4, 5, respectively, for the responses Almost Never, Seldom, Sometimes, Often, Very Often. Items designated (-) are scored in the reverse manner. Missing or invalid responses are scored 3.

Results

The perceptions of the chemistry laboratory classroom environment of male and female students were compared using a multivariate analysis of variance (MANOVA). This analysis confirmed that significant differences existed overall between sexes. This justified an examination of each of the 10 Chemistry Laboratory Environment Inventory (CLEI) scales individually using a two-way univariate analysis of variance (ANOVA). 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 sexes for the seven cases shown in Table 2. The unit of analysis used in these analyses was the sex subgroup mean for each class (i.e., male subgroup mean and female subgroup mean within each class) so that a meaningful test of within-class sex differences could be accomplished.

The scale means and standard deviations for the actual and preferred perception scores calculated across the 50 coeducational classes for the male and female students' perception scores on the actual and preferred versions of CLEI are tabulated in Table 2. The item mean for each scale also was calculated and reported in the last two columns of the table to provide a meaningful basis for comparing scores on different scales.
In addition, a simplified plot of the statistically significant differences ($p<0.05$) between the mean scores obtained by male and female students on each of the actual and preferred scales of the CLEI was drawn. Figure 1 therefore represents the simplified plot of the results in Table 2. The response alternatives of the CLEI instrument

corresponding to the value intervals on the item mean axis in both of these figures are also as follows: 1 = `Never', 2 = `Seldom', 3 = `Sometimes', 4 = `Often', and 5 = `Very Often'.

An examination of Table 2 and Figure 1 show that male and female students differed significantly ($p<0.01$) in their perceptions of the actual chemistry laboratory class environment for two of the five CLEI scales, namely, Integration and Open-Endedness. On the average, 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, while male students perceived the occurrence of open-endedness more frequently than the female students did. Each of these differences had an effect size (i.e., the difference between two groups expressed in terms of standard deviation for both groups) 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 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.

TABLE 2 : Scale Means and Standard Deviations for the Actual and Preferred Versions of the CLEI for Male and Female Students

Figure 1: Simplified Plot of Significant Differences between Male and Female Actual and Preferred Perception Scores

Table 2 and Figure 1 show that the preferred perception scores of male and female students differed significantly ($p<0.05$) for all five CLEI scales. The plots show that 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. These differences amounted to an effect size of approximately one-third of a standard deviation for Student Cohesiveness, and over half a standard deviation for Integration, Rule Clarity and Material Environment, all in favour of the female students. This could indicate that female students could be 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 approximately 0.4 in favour of the male students was found (i.e., males preferred laboratory activities to be more open-ended than females).

Although the effect sizes obtained may not seem relatively large, they are acceptable because effect sizes in education typically is modest and averages only 0.4 standard deviations as reported by Fraser, Walberg, Welch and Hattie (1987) in their synthesis of 134 meta-analyses encompassing 7,827 students. Hence, the effect sizes reported here do indicate ttha there is a difference between the perceptions of male and female students.

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. 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 generally 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; Fraser, Giddings & McRobbie, 1995). 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.

Discussion and Conclusion

The results in this study show that there are sex-related differences in student perception of the actual as well as the preferred (ideal) chemistry laboratory psychosocial environment. In general, female students tended to perceive their learning environment more favourably than the male students. This finding further supports previous studies

in the area of learning environment (Lawrenz, 1987; Giddings & Fraser, 1990; Fraser et al., 1992b).

In their perceptions of the 'actual' laboratory environment, both male and female students felt the same the same way about the level of Student Cohesiveness, Rule Clarity and Material Environment. They felt that peer support and cooperation (Student Cohesiveness) were 'often' exhibited, teachers 'often' gave clear rules (Rule Clarity), and laboratory equipment and materials were adequate only 'sometimes' (Material Environment).

However, although both sexes indicated that Integration was 'often' practised, female students perceived Integration more favourably than the male students. This seems to imply that the female students were able to appreciate the link between what they learn in theory and what they do in the laboratory better than their male counterparts. Or it could also imply that the male students were more critical about how their teachers effected this theory-practice linkage.

For the dimension of Open-Endedness, although both sexes indicated that it was 'seldom' practised, male students had significantly more favourable perceptions of it than their female counterparts. This could mean that, although all students were given the same experiments to carry out, teachers allowed male students to work more on their own, whereas they provided more guidance and help to the female students. Hence the male students would view a greater occurrence of open-endedness than their female counterparts.

When the perceptions of the 'ideal' laboratory environment were compared, male and female students differed significantly in their perceptions of all five environment dimensions. With the exception of the Open-Endedness scale, female students would prefer higher occurrences of peer support (Student Cohesiveness), theory-practice linkage (Integration), clarity of rules (Rule Clarity) and equipment/material adequacy (Material Environment). They are probably

less contented with their present laboratory environment This finding seems to imply that female students are more idealistic than their male counterparts. Could this trait be sex-related?

However, for the Open-Endedness scale, the male students indicated that they would like to have greater divergence and open-endedness in their practical work than the female students. It would seem that males prefer challenges more than females. Is this trait also sex-related?

Overall, female students in this study were found to perceive their learning environment more favourably than male students, except in the area of Open-Endedness. There is thus a possibility that teachers treat male and female students differently, resulting in a difference in perception. For example, teachers are likely to provide female students with more guidance in their experimental work. This probably would lead female students to perceive and/or prefer/expect higher levels of Students Cohesiveness, Integration, Rule Clarity and even Material Environment, but definitely a lower level of Open-Endedness. This finding would mean that there is a need for chemistry teachers to adjust the environment of their laboratory classrooms so as to promote greater equality of treatment of the sexes. They should try to handle their laboratory procedures more fairly, giving both males and females similar amounts of guidance and equal opportunities for participation and exploration. This would help close the gender-gap resulting in a more conducive classroom environment for both teachers and students.

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