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ABSTRACT

This study examined the nature and impact of two aspects of classroom learning (interpersonal teacher behavior and classroom climate) on the affective and cognitive outcomes of elementary mathematics students in Singapore. A secondary purpose was to explore gender differences in students' achievement, attitudes, and perceptions of the classroom environment. A random sample of 1,512 boys and girls from government elementary schools was used. For the analysis of environment-outcome associations, simple, multiple, and canonical correlation analyses and multilevel (hierarchical linear model) analyses were conducted using two units of analysis, the individual student and the class mean. For the analysis of gender differences, multivariate analyses of variance (MANOVA) for repeated measures were performed for the two outcome measures and the classroom environment scales. Overall the different methods of analysis yielded consistent associations between classroom environment and student outcomes. Gender differences were detected in mathematics achievement in favor of boys, but girls generally viewed their classroom environment more favorably than the boys did. (Author)

LEARNING ENVIRONMENT AND STUDENT OUTCOMES IN PRIMARY MATHEMATICS CLASSROOMS IN SINGAPORE

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Abstract

This study was undertaken to examine the nature and impact of two aspects of classroom learning environment (interpersonal teacher behavior and classroom climate) on the affective and cognitive outcomes of elementary mathematics students in Singapore. A secondary purpose was to explore gender differences in students' achievement, attitudes, and perceptions of classroom environment. A random sample of 1,512 boys and girls from government elementary schools was used. For the analysis of environment-outcome associations, simple, multiple and canonical correlation analyses and multilevel (hierarchical linear model) analyses were conducted using two units of analysis, the individual student and the class mean. For the analysis of gender differences, multivariate analyses of variance (MANOVA) for repeated measures were performed for the two outcome measures and the classroom environment scales. Overall the different methods of analysis yielded consistent associations between classroom environment and student outcomes. Gender differences were detected in mathematics achievement, in favor of boys, but girls generally viewed their classroom environment more favorably than the boys did.

Paper presented at the annual meeting of the American Educational Research Association (AERA), San Francisco, April, 1995.

Learning Environment and Student Outcomes in Primary Mathematics Classrooms in Singapore

Swee Chiew Goh and Barry J. Fraser

Within the context of the search for more effective ways to enhance the teaching-learning process, educational researchers have proposed different frameworks and methods to examine what accounts for the variations in student learning within a classroom (e.g., Kounin, 1970; Berliner, 1983; Doyle, 1986; Galton, 1987; Brophy, 1988; Shulman, 1990). Most researchers would agree that any thorough analysis of the nature of the learning environment – the classroom – must consider the key players involved, namely, the teacher and his/her students. The collective nature of the classroom has been described in various terms such as 'dynamic', 'complex', 'interactive' and 'interpersonal'. The interplay of the behavior of both the teacher and the students determines the classroom climate or the psychosocial climate. Classroom practices and developments, particularly during the last 30 years, have indicated that a positive classroom climate is needed before learning can take place (Brophy & Putnam, 1979; Emmer, Evertson & Anderson, 1980).

The concept of a learning environment probably has taken root since the 1930s, especially with the emergence of Murray's Need-Press model (1938) and Kurt Lewin's social-psychological climate (1936). In 1960, a framework for the analysis of the classroom group as a unique social system was developed by Getzels & Thelen (1960). Later, Doyle (1979) proposed viewing the classroom from an ecological viewpoint, hence placing strong emphasis on the inter-relationships and communications among all members in the classroom community. On the other hand, Berliner (1986) described the classroom as a workplace and a teacher as an executive who manages the workplace. Generally, teacher effectiveness was examined from the perspective of the teacher as a manager of both student learning and behavior in the classroom. *The Seventy-eighth Yearbook of the National Society for the Study of Education* (NSSE, 1979), dedicated to classroom management, stressed the importance of the human factor in the classroom environment (Johnson & Brooks, 1979). Learning activities, whether planned and coordinated, always are accompanied by interpersonal interaction and intrapersonal sentiments. This human element, consisting of the feelings and sentiments of teacher and students, has made the classroom complex and unpredictable (Doyle, 1983). This also confirms the observation of Moos (1979a, 1979b) that one important aspect of the learning environment is the nature of the communication between teacher and students. As Watzlawick, Beavin & Jackson (1967) put it succinctly, 'one cannot NOT communicate' (p. 51, block letters added).

It is the reciprocal nature of this teacher-student communication that makes it a powerful force in influencing the learning environment and subsequently student performance. In the last 20 odd years, this long-standing recognition has inspired a tradition of studying classroom learning environment through the perceptions of both teachers and students (MacAulay, 1990; Fraser & Walberg, 1991; Fraser, 1993, Fraser, 1994). In addition, in an attempt to understand better the impact of teacher-student communication in the learning process, Wubbels and his colleagues embarked on the study of interpersonal teacher behavior (Wubbels, Brekelmans & Hermans, 1987; Creton, Hermans & Wubbels, 1990; Wubbels, 1993) in secondary classrooms. As the behavior of both teacher and student influence each other mutually, teacher-student interactional behavior is assumed to be of crucial importance to student learning in the classroom.

In the past decades, considerable interest has been focused also on the teaching and learning of mathematics in schools (Forsyth & Spratt, 1980; Korbosky, 1989; Romberg, Carpenter, White & Tisher, 1990; Fraser & Tobin, 1993). This field of research includes studies of gender differences in mathematics classrooms (Ethington, 1990; Fennema & Peterson, 1985; Fennema & Leder, 1990; Kahle & Meece, 1994; Parker, Rennie & Fraser, in press). It has been shown that there are gender differences in mathematics classrooms, including in teacher-student interactions (Eccles & Blumenfeld, 1985; Koehler, 1990) and student achievement (Hanna, 1989; Hensel, 1989), which are two areas relevant to this study.

The Singapore Scenario

Although the study of learning environments has a history of 25 years in other countries, it made its first appearance in Singapore only recently with a study of student perceptions of their classroom climate in a computer-assisted learning environment (Teh & Fraser, 1994a, 1994b). This study resulted in the development and validation of a new instrument for learning environment research, termed the Geography Classroom Environment Inventory (GCEI). It also established that computer-assisted learning for slower secondary students was a more efficacious instructional methodology in comparison with a traditional teaching method. Furthermore, an investigation of associations between student outcomes and computer-assisted learning environment in secondary geography classes replicated past research in that achievement and attitudes were better in classes perceived to have positive classroom environments.

Another Singaporean study using the Individualised Classroom Environment Questionnaire (ICEQ) concerned the perceptions of secondary students of their classroom climate across different types of schools, streams and subject specialisations (Lim, 1993). The study indicated, among other things, that students preferred a more positive and favourable classroom environment than actually was prevalent.

The latest study (Wong & Fraser, 1994) focused on determinants and effects of chemistry laboratory settings in secondary schools. It revealed differences in perceptions between teachers and students, that preferred chemistry laboratory environments were more favourable than actual perceptions, and that students from different streams differed only in their preferred perceptions. Investigation of relationships between student affective outcome and the perceived environment of chemistry laboratories and research into gender differences in perceptions generally replicated earlier findings.

Apart from the above-mentioned studies in secondary schools, there was a small-scale study in one primary school (Ong, 1987) assessing the possible relationship between classroom management and classroom environment.

As practically all studies in Singapore were undertaken in secondary classrooms, it was timely to initiate a study of classroom environment at the primary level, focusing on interpersonal teacher behavior and classroom climate. Therefore, it was appropriate to use a specially-adapted primary version of the QTI and the MCI to examine, through student perceptions, the impact of teacher-student relationships and classroom climate on student cognitive and affective outcomes in primary mathematics classes. This study enjoys the distinction of being the first classroom learning environment research done in primary mathematics classes in Singapore.

Research on gender differences in mathematics learning in Singapore is comparatively scarce (Ministry of Education, 1988; Kaur, 1992). Despite the paucity of research in this area, it is evident that a gender gap does exist in mathematics achievement among Singaporean students (Kaur, 1992). Currently, considerable educational research in Singapore focuses on issues and problems relating to secondary schools. Less research work has been done concerning primary schools, even in the developed western countries (Raviv, Raviv & Reisel, 1990).

This realisation that teacher-student interpersonal relationships are likely to affect the learning outcomes of students led to the present study of the nature and classroom environment and its effect on student learning. This study was conceptualised with three main elements in mind: the teacher, the students and the context. The teacher and the students are the key players in the classroom context. The interaction among the teacher, the students and the context determines the type of classroom climate, which in turn influences student outcomes.

This investigation into the nature and impact of relationships among the teacher-student-context triad at the Grade 5 level was considered desirable and meaningful. Because the students are more mature and at a higher stage of psychological development than students at lower grade levels, students at Grade 5 level (aged 11–12 years) are more capable of making decisions or evaluations regarding the competencies and behaviors of their teachers and other classroom events. The Grade 5 level is also just before the final year of elementary schooling, and therefore findings from this important grade level are likely to provide a valuable source of information for school administrators and teachers for decision-making at the Grade 6 level. Schools are aware of the importance of examination results obtained in the all-important Primary School Leaving Examination (PSLE) at the end of the six-year elementary school education. With the increasing emphasis on educational excellence, it is even more desirable to study developments, practices and issues affecting the elementary schools in Singapore.

In the Singapore elementary school curriculum, the teaching of mathematics and languages (English as a first language and mother-tongue as a second language) are equally important, beginning with the pre-primary stage right through the elementary school into secondary and post-secondary schooling. Great importance is attached to the teaching/learning of mathematics, as seen in the large number of workshops related to mathematics teaching organised specially for teachers. In addition, the Ministry of Education has established a special committee within the Curriculum Development Institute of Singapore to develop computer-based learning in primary mathematics. Yet this is a subject that evidently draws both love and hate from students. As reported in Yip and Sim (1990), a study by the Ministry of Education (1988) into the relationship between examination performance and sex and birth-month indicated that, at Grade 3 level (about nine years of age), girls did better than boys in mathematics, while the situation was reversed in favour of boys at the Primary School Leaving Examination level (i.e., Grade 6 level and students are about 12 years old). In view of the importance of mathematics in the school curriculum, it was both timely and beneficial to examine whether the teacher-student-context triad promotes or hinders student liking for mathematics and whether it also affects student achievement in elementary schools in Singapore. This study was not really concerned with problems of instruction, nor is it directly concerned with the learning of mathematics concepts and skills. The emphasis of this study of the mathematics classroom environment was not on how mathematics is learned but how teacher-student relationships and classroom climate might affect Grade 5 student's learning of mathematics, particularly in the cognitive and affective areas.

Design and Methods

Sample

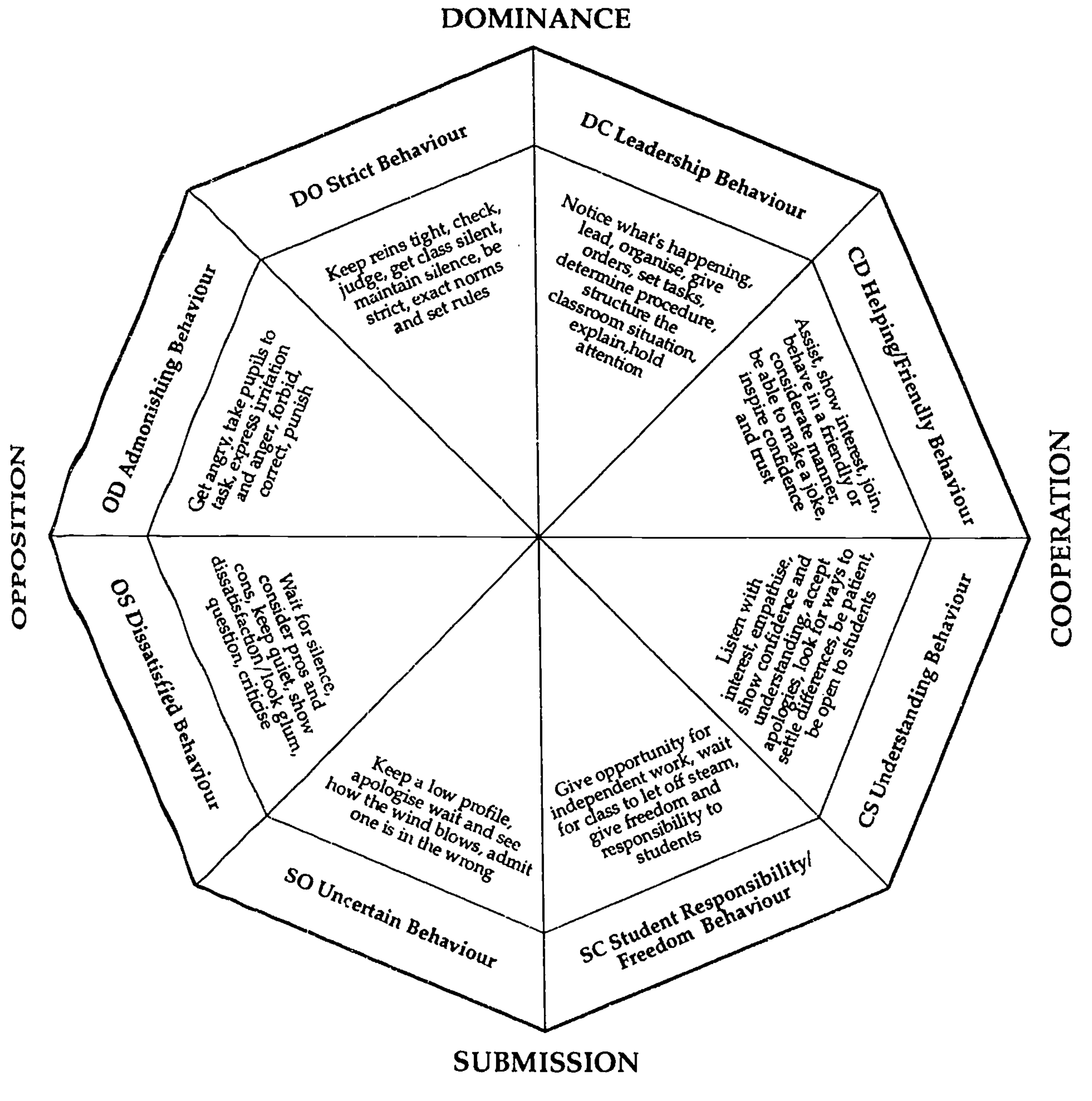
A random sample of 39 mathematics classes from 13 government coeducational elementary schools provided (1) a teacher sample size of 39 mathematics teachers, one for each of the 39 classes and (2) a student sample size of 1,512, comprising 815 boys and 697 girls. These boys and girls were 10 to 11 years of age, of mixed ability, and in the EM2 stream (where they learn English as a first language, Chinese/Malay/Tamil as a second language, Mathematics and Science). These 39 classes were intact classes because the principals gave the researchers permission only to administer the questionnaires to whole classes during mathematics curriculum time.

Instruments

The four instruments used in this study of learning environment in elementary mathematics classroom were the *Questionnaire on Teacher Interaction(Primary)*, the *My Class Inventory*,) the *Liking Mathematics Scale*, and the *Mathematics Exercise*.

A new elementary version, the *Questionnaire on Teacher Interaction/Primary*, was adapted from two versions of the *Questionnaire on Teacher Interaction (QTI)* for secondary schools: the long form QTI (of 64 items) used in an Australian study and the short form QTI (of 48 items) designed for Australian teachers to obtain feedback from their classes (Wubbels, 1993). The original version of the QTI is an instrument designed in The Netherlands (Wubbels, Brekelmans and Hooymayers, 1991) for measuring interpersonal teacher behavior in the classroom. The QTI was translated from Dutch into English and cross-validated in the USA (Wubbels and Levy, 1991). Subsequently, the QTI was used in various studies in Israel (Kremer-Hayon and Wubbels, 1992) and Australia (Wubbels, 1993). The present study involved further adaptation of the QTI to make it suitable for use at the elementary level, and its subsequent validation in Singapore. The measure of interpersonal teacher behavior was based on student perceptions on the 48-item short form QTI (Primary) which assesses eight dimensions: Leadership (DC), Helping/Friendly (CD), Understanding (CS), Student Responsibility/Freedom (SC), Uncertain (SO), Dissatisfied (OS), Admonishing(OD) and Strict (DO) behavior. The QTI consists of these eight scales of teacher

Figure 1: Model of Interpersonal Teacher Behavior



behavior corresponding to the eight sectors of the modified Leary model for interpersonal teacher behavior as presented in Figure 1. For instance, Figure 1 illustrates what Leadership behavior encompasses by stating typical teacher behaviors which include "notice what's happening, lead, organise, give orders, set tasks, determine procedure, structure the classroom situation, explain and hold attention.

The *My Class Inventory* (MCI, Fisher & Fraser, 1981) is a 20-item classroom environment instrument which provided the information regarding student perceptions of the four classroom climate scales of Cohesion, Competition, Friction and Task Orientation.

The affective outcome, the *Liking Mathematics Scale* (LMS), was based on a 10-item instrument developed specifically by the researchers to measure student liking and interest for mathematics, with guidance provided by attitude scales developed by Keeves (1974) and Fraser (1981).

Student cognitive achievement was assessed with a 10-item mathematics achievement test, the *Mathematics Exercise* (ME), the framework for which was provided by a sample of school mathematics assessment papers and primary mathematics textbooks and workbooks. This instrument was developed by the researchers in three stages, taking cognizance of the importance of feedback from experts in the field (school mathematics teachers and mathematics experts or content experts). The 10 items in the ME were developed after a thorough examination of the mathematics syllabi for Grades 4 and 5. Each of the items was designed with a problem/situation as the stem and four multiple-choice alternatives. As for the QTI (Primary), the MCI and the LMS, students respond to a three-point Likert scale consisting of Most of the Time, Sometimes and Seldom.

Pilot Testing of Instruments

A pilot study was carried out with two Grade 5 classes of the EM2 stream in one government primary school. The main purpose of this field test was the gathering of subjective information to guide smooth administration during the main study. This field testing was also necessary to evaluate (1) the comprehensibility and clarity of the items in the four instruments (the QTI/P, MCI, LMS and ME), (2) the suitability of the three-point Likert response scale consisting of Seldom, Sometimes and Most of the Time for the three questionnaires (QTI, MCI and LMS), (3) the procedures for data collection, and (4) the approximate amount of time required by students to complete each of the instruments. In addition, the researchers interviewed six students concerning the clarity of the instruments and the three-point rating scale.

To improve the comprehensibility and clarity of the instruments, especially the QTI, difficult words identified by students during interview were substituted with simpler words, if possible or appropriate. Also, a few other items were reworded to ensure that the reading level was more appropriate. With regard to the response format in the questionnaires, it was found to be appealing and clear to the students. The procedures used for data collection in the two classes proved logical and systematic, and students found the directions simple and straightforward. Overall, the total time taken by the students to respond to the instruments was about an hour.

Data Collection

The researchers personally administered the four instruments in every class involved in the main study. Students used 2B pencils to shade their responses on Optical Answer Sheet (OAS), a process with which they were familiar during school assessments. Students began with the QTI(P) and, after a short rest, responded to the MCI, LMS and ME. The questionnaires and mathematics exercise were printed on coloured paper to provide an easy name reference in class and to add variety to the process.

Validation of Instruments with Elementary Students in Singapore

Questionnaire on Teacher Interaction (QTI)

Data for the random sample of 1,512 students were analysed to furnish evidence for each QTI scale regarding internal consistency reliability, scale intercorrelations, and ability to differentiate between classrooms. The Cronbach alpha coefficient was computed for each QTI scale as a measure of internal consistency reliability. Table 1 reports internal consistency reliabilities at two levels of analysis, namely, the individual student score (N=1,512) and the class mean score (N=39). The data in Table 1 suggest that the QTI (Primary) has quite good reliability, with five out of eight scales (namely, Leadership, Helping/Friendly, Understanding, Dissatisfied and Admonishing) having values above 0.90 for class means, and the same five scales having values between 0.63 and 0.78 for individual students. As expected, the reliability estimates were higher when the class mean was used as the unit of analysis. These values for Singapore are comparable to those reported by Wubbels (1993) and Wubbels and Levy (1991) for secondary students in The Netherlands, the USA and Australia. In all four countries, the highest reliability occurred for Helping/Friendly teacher behavior and the lowest for Student Responsibility/Freedom behavior. Overall data in Table 1 appear to confirm further the comparatively high reliability of the QTI (Primary), especially for short scales containing only six items each.

Table 1: Internal Consistency Reliability (Cronbach Alpha Coefficient) for Two Units of Analysis and Ability to Differentiate between Classrooms (ANOVA Results) for the Questionnaire on Teacher Interaction (Primary)

QTI Scale	Alpha Reliability		ANOVA Eta^2
	Individual N=1,512	Class Mean N=39	Individual N=1,512
Leadership (DC)	0.63	0.90	0.18**
Helping/Friendly (CD)	0.78	0.96	0.38**
Understanding (CS)	0.65	0.94	0.30**
Student Responsibility/Freedom (SC)	0.58	0.73	0.13**
Uncertain (SO)	0.50	0.83	0.15**
Dissatisfied (OS)	0.76	0.96	0.33**
Admonishing (OD)	0.74	0.93	0.35**
Strict (DO)	0.58	0.81	0.15**

** $p<0.01$
The eta^2 (the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

Further evidence regarding the validity of the primary version of the QTI was obtained by examining the scale intercorrelation matrix presented in Table 2 for two units of analysis (the individual student and the class mean). According to the circumplex model described in Figure 1, adjacent behavior scales (for example, Helping/Friendly, CD, and Understanding, CS), should correlate highest and positively with each other, and the magnitude of the correlation should diminish as the scales become increasingly different as they move further apart from each other until they are diametrically opposite to each other. Diametrically opposite scales, such as Helping/Friendly (CD) and Dissatisfied (OS), should have the highest negative correlation (Wubbels, 1993). Overall, the QTI scale intercorrelations shown in Table 2 satisfy this assumption with minor discrepancies.

Table 2 Scale Intercorrelations for Each QTI Scale Using Individual Students and Classes as Units of Analysis

QTI Scale	Scale Intercorrelations							
	Leadership (DC)	Helping/ Friendly (CD)	Understanding (CS)	Student Responsibility (SC)	Uncertain (SO)	Dissatisfied (OS)	Admonishing (OD)	Strict (DO)
Leadership (DC)	-	0.60	0.60	0.10	-0.34	-0.43	-0.42	0.11
Helping/Friendly (CD)	0.90	-	0.65	0.26	-0.28	-0.61	-0.59	-0.13
Understanding (CS)	0.92	0.91	-	0.32	-0.24	-0.48	-0.48	-0.03
Student Responsibility/ Freedom (SC)	0.52	0.61	0.64	-	0.19	-0.11	-0.11	-0.21
Uncertain (SO)	-0.74	-0.61	-0.67	-0.20	-	0.42	0.41	-0.01
Dissatisfied (OS)	-0.85	-0.90	-0.89	-0.57	0.69	-	0.76	0.31
Admonishing (OD)	-0.76	-0.83	-0.86	-0.57	0.65	0.95	-	0.32
Strict (DO)	-0.21	-0.42	-0.38	-0.38	0.16	0.57	0.65	-

Data above the diagonal are for individual students, while data below the diagonal are for class means.

Figure 2: Profile of Scale Intercorrelations for Helping/Friendly Scale Using Class Unit of Analysis

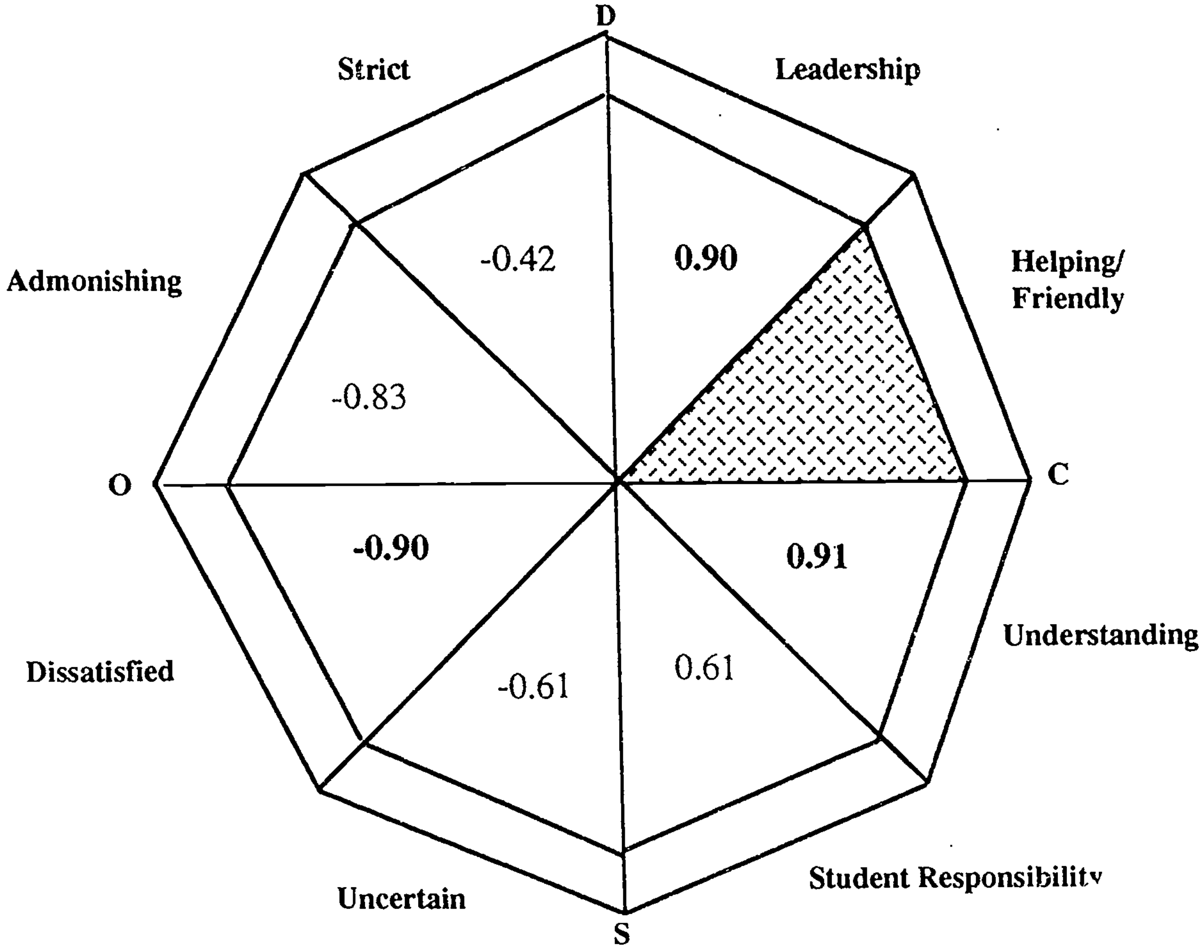


Figure 2 illustrates this characteristic assumption of the circumplex model of interpersonal teacher behavior using the Helping/Friendly (CD) scale's correlations to its adjacent and opposite scales. At the class level of analysis, adjacent scales of Leadership (DC) and Understanding (CS) correlate highest and positively with Helping/Friendly (CD), showing values of 0.90 and 0.91, respectively. This correlation becomes smaller for scales located further from each other, and the directly opposite scale of Dissatisfied (OS) has the highest negative correlation of -0.90.

It is desirable for students within a class to see their classroom environment relatively similarly, and for average class perceptions to vary from class to class. A series of analyses of variance, with class membership as the main effect, revealed significant differences (p<0.01) for every scale on the QTI between the perceptions of students in different classes. The eta^2 statistic, which represents the amount of variance in interpersonal teacher behavior scores accounted for by class membership, ranged from 0.13 to 0.38 (Table 1).

My Class Inventory

The modified version of the MCI was administered to the same sample which responded to the QTI. The MCI was administered during mathematics curriculum time and in the absence of the mathematics teachers in order to ensure that student responses would not be inhibited somewhat by the presence of their teachers. A series of data analyses was conducted to establish the MCI's internal consistency reliability, discriminant validity and ability to differentiate between perceptions of students in different classes.

As a measure of internal consistency reliability, the Cronbach alpha coefficient was calculated for each MCI scale. Table 3 reports the internal consistency of the MCI for students' perceptions at two levels of analysis: the individual student score and the class mean score. The alpha reliability figures in Table 3 show that three out of four MCI scales (Cohesion, Friction and Task Orientation) have values above 0.90 for the analysis at the class level. These values for Cohesion and Friction are higher than those reported in Fraser, Malone & Neale (1989) as 0.81 and 0.70, respectively. Table 3 also shows that the alpha reliability for the Competition scale is 0.75, and this compares favourably with its counterpart's reliability value of 0.70 as reported in Fraser, Malone & Neale (1989). For the analysis at the individual student level, two of the scales (Cohesion and Friction) have reliability values of 0.73 and 0.75, respectively, which are higher than their counterparts reported by Fraser & Fisher (1982a). The data reported in Table 3 suggest that the MCI scales have good internal consistency reliability for use with either students or classes as the unit of analysis.

Table 3 Internal Consistency Reliability (Cronbach Alpha Coefficient) and Discriminant Validity (Mean Correlation with other Scales) for Two Units of Analysis and ANOVA Results for Class Membership Differences for My Class Inventory

MCI Scale	Alpha Reliability		Mean Correlation with Other Scales		ANOVA Eta2
	Individual N=1,512	Class Mean N=39	Individual N=1,512	Class Mean N=39	Individual N=1,512
Cohesion	0.73	0.92	0.32	0.58	0.10 **
Competition	0.56	0.75	0.31	0.47	0.07 **
Friction	0.75	0.94	0.42	0.67	0.24 **
Task Orientation	0.68	0.92	0.39	0.53	0.17 **

** $p < 0.01$
The eta2 (the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

Second, data concerning discriminant validity were obtained by using the mean correlation of a scale with the other three scales of the MCI and are presented in the centre column of Table 3. The data indicate that the discriminant validity of these scales is satisfactory, but suggest that the MCI assesses distinct but somewhat overlapping aspects of learning environment.

Third, a series of analyses of variance with class membership as the main effect and using the individual as the unit of analysis indicated significant differences (p <0.01) for every scale on the MCI between the perceptions of students in different classes. It is desirable that students within a class view their classroom environment relatively similarly but that there are between-class differences in average environment scores. The eta2 statistics, which provide an estimate of the amount of variance in classroom climate scores attributable to class membership, ranged from 0.07 to 0.24 (see last column of Table 3).

Environment-Outcome Associations

The primary purpose of this study was to examine associations between two aspects of classroom environment (interpersonal teacher behavior and classroom climate) and student outcomes (attitude and achievement). In order to explore outcome-environment associations, the data were subjected to a series of correlational analyses (including simple, multiple and canonical) and multilevel (hierarchical linear model) analyses, using two levels of analysis (the student and the class). In addition, a commonality analysis was undertaken to examine the joint and unique contributions of interpersonal teacher behavior and classroom climate to variance in student outcomes. For the analysis of gender differences, multivariate analyses of variance (MANOVA) for repeated measures were performed for the measures of outcome and classroom environment.

Correlational and Multilevel Analyses of Interpersonal Teacher Behavior and Student Outcomes

Using both the student and class levels of analysis, findings from the analysis of outcome-environment associations replicated the finding in past research of the strong influence of interpersonal teacher behavior and classroom climate on student learning (Haertel, Walberg & Haertel, 1981; Fraser & Fisher, 1982a, 1982b; McRobbie & Fraser, 1993a; Wubbels, 1993; Fraser, 1994). Table 4 presents the results of simple, multiple and canonical analyses separately for student outcome (Liking and Achievement).

In addition to the simple, multiple and canonical correlational analyses reported in Table 4, a multilevel analysis was computed on the inherently hierarchical data for the 1,512 students from 39 intact mathematics classes to ensure that adequate consideration was given to the variability between individual students and between classes arising from the nesting of students within classrooms and schools. The model of multilevel analysis used in this study was the Hierarchical Linear Model (HLM), which provides an integrated strategy for handling problems such as aggregation bias in standard error estimates and imprecision (Bryk & Raudenbush, 1988). The computer package, HLM2L (Bryk, Raudenbush, Seltzer & Congdon, 1989), was used. The inclusion of multilevel analysis in learning environment research is relatively new and promises to be potentially beneficial.

Overall, the various analyses represented in Table 4 suggest that teachers can foster favourable student affective and cognitive outcomes through interactions showing more Leadership, Helping/Friendly and Understanding behavior and less Uncertain, Dissatisfied and Admonishing behavior.

Table 4 Simple Correlations (r), Multiple Correlations (R), Canonical Correlations and Standardised Regression Coefficients (ß) Between QTI and Student Outcomes for Two Units of Analysis

QTI Scale	Unit of Analysis	Simple Correlation, r		Standardised Regression Coefficient, ß	
		Liking	Achievement	Liking	Achievement
Leadership (DC)	Individual	0.41 **	0.28 **	0.15 *	0.10 *
	Class Mean	0.80 **	0.68 **	-0.17	0.65
Helping/Friendly (CD)	Individual	0.43 **	0.25 **	0.20 *	-0.02
	Class Mean	0.80 **	0.51 **	0.57 *	-0.61
Understanding (CS)	Individual	0.36 **	0.30 **	0.07 *	0.17 *
	Class Mean	0.81 **	0.61 **	0.40 *	0.09
Student Responsibility/ Freedom (SC)	Individual	0.01	0.07 **	-0.07 *	0.04
	Class Mean	0.44 **	0.32	0.00	0.18
Uncertain (SO)	Individual	-0.28 **	-0.28 **	-0.07 *	-0.20 *
	Class Mean	-0.77 **	-0.75 **	-0.51 *	-0.59 *
Dissatisfied (OS)	Individual	-0.38 **	-0.25 **	-0.10 *	0.06
	Class Mean	-0.76 **	-0.59 **	0.47	-0.37
Admonishing (OD)	Individual	-0.37 **	-0.23 **	-0.07 *	0.01
	Class Mean	-0.74 **	-0.52 **	-0.14	0.52
Strict (DO)	Individual	-0.02	-0.00	0.03	0.01
	Class Mean	-0.30	-0.15	-0.05	-0.20
Multiple Correlation, R	Individual			0.51 **	0.38 **
	Class Mean			0.89 **	0.82 **
Canonical Correlation	Individual			0.54 **	
	Class Mean			0.92 **	

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

As this study incorporated the use of two methodological approaches for the analysis of the same set of data, Table 5 presents a comparison of results from the multiple linear regression and hierarchical linear model regression analyses. Table 5 indicates that the results from the HLM and multiple regression analyses were identical in terms of both patterns of significance and the direction of relationships for three predictors of student outcomes for both levels of analysis (student or class levels). These three predictors are Leadership, Student Responsibility/Freedom, and Dissatisfied teacher behaviors. Different patterns of significance emerged for Helping/Friendly, Understanding, Uncertain and Admonishing behaviors, depending on the level of analysis. Strict teacher behavior shows consistently nonsignificant linkage to student variance for both HLM and multiple regression analyses at either level of analysis.

Table 5 A Comparison of Multiple Linear Regression and Hierarchical Linear Model Regression Results for Interpersonal Teacher Behavior Scales and Student Outcomes at Two Levels of Analysis (Individual and Class Mean)

QTI Scale	Unit of Analysis	Multiple Linear Regression Coefficients		Hierarchical Linear Model Regression Coefficients	
		Liking	Achievement	Liking	Achievement
Leadership (DC)	Individual	0.15 *	0.10 *	0.34*	0.08*
	Class Mean	-0.17	0.65	-0.70	0.96
Helping/Friendly (CD)	Individual	0.20 *	-0.02	0.31*	-0.02
	Class Mean	0.57 *	-0.61	0.30	-0.52
Understanding (CS)	Individual	0.07 *	0.17 *	0.09	0.11*
	Class Mean	0.40 *	0.09	0.40	-0.01
Student Responsibility/ Freedom (SC)	Individual	-0.07 *	0.04	-0.18*	0.01
	Class Mean	0.00	0.18	0.16	0.36
Uncertain (SO)	Individual	-0.07 *	-0.20 *	-0.10	-0.15*
	Class Mean	-0.51 *	-0.59 *	-0.19*	-1.12*
Dissatisfied (OS)	Individual	-0.10 *	0.06	-0.20*	0.01
	Class Mean	0.47	-0.37	0.75	-0.37
Admonishing (OD)	Individual	-0.07 *	0.01	-0.09	0.01
	Class Mean	-0.14	0.52	-0.06	0.47
Strict (DO)	Individual	0.03	0.01	0.05	0.02
	Class Mean	-0.05	-0.20	-0.14	-0.34

* $p<0.05$

With regard to the overall picture detected from the multiple regression and HLM analyses concerning associations between teacher behavior and the two student outcomes, the multiple regression analysis (also reported previously in Table 4) indicated 14 significant values, as opposed to nine for the HLM analysis. The five significant values (that of Helping/Friendly, Understanding, Uncertain and Admonishing teacher behavior scales) in the multiple regression analysis that were not replicated in the multilevel analysis pertained only to associations between teacher behavior and student attitude, and are discussed later in this section.

It is interesting to note that, in terms of the inter-relationships between teacher behaviors and student achievement, the same four significant results were obtained for the HLM and multiple regression analyses: Leadership (DC) at the individual student level; Understanding (CS) at the individual level; and Uncertain (SO) teacher behavior at both levels of analysis.

On the other hand, the multiple regression and HLM analyses concerning significant associations between teacher behavior and student affective outcomes were not as consistent as for student achievement. Similar significant associations were found for Leadership (DC), Helping/Friendly (CD), Student Responsibility/Freedom (SC) and Dissatisfied (OS) teacher behaviors at the individual level and Uncertain (SO) teacher behavior at the class level. However, five significant values in the multiple regression analysis were not replicated in the HLM analysis. The most distinct yet paradoxical difference revealed in Table 5 pertained to the teacher behavior scale Understanding (CS) and student liking for mathematics at both levels. There was no significant association between teacher understanding and student liking for mathematics at either level of analysis using the HLM approach, though the multiple linear regression indicated a significant association at both levels. The second difference occurred for the relationship between Helping/Friendly (CD) teacher behavior and student affective outcome at the class level of analysis. In contrast to the multple regression results, the HLM analysis showed no significant relationship between teacher Helping/Friendly behavior and student liking for mathematics. The third difference concerned the negative relationship between teacher Uncertain behavior and student liking for mathematics that was statistically significant in the multiple regression analysis (at the individual student level) but was not significant in the multilevel analysis. Lastly, the significant negative relationship of teacher Admonishing behavior and student liking for mathematics in the multiple regression analysis (at the individual student level) was not replicated in the HLM analysis.

Generally, findings from the HLM analyses were consistent with the findings of traditional simple, multiple and canonical correlation analyses. The multilevel analysis suggests that the types of teacher behavior that are associated with student learning were identified as Understanding, Helping/Friendly and Leadership teacher behaviors, and to a lesser degree, Student Responsibility/ Freedom teacher behavior. These can be classified as positive teacher behaviors that not only foster positive student attitudes towards mathematics learning but also bring about higher achievement scores. Therefore, it is desirable for primary mathematics teachers in Singapore to cultivate consciously these positive behaviors and exhibit them more often in their interactions with students.

Secondly, Uncertain teacher behavior emerged as an important negative teacher behavior that influences for the worse student attitudinal and cognitive outcomes. For better student outcomes, teachers should refrain from demonstrating Uncertain behavior in classroom interactions.

Thirdly, Strict teacher behavior did not seem to influence either student attitudes towards learning of mathematics or student achievement. Teachers, thus, need not feel anxious about undesirable side effects associated with being either too strict or not strict enough with students.

Correlational and Multilevel Analyses of Classroom Climate and Student Outcomes

Using data analysis methods identical to those used for the QTI (see Table 4), data obtained from the MCI, the LMS and the ME were analysed and presented in Table 6. As in the case of associations betweeen interpersonal teacher behavior and student outcomes discussed previously, there was a strong relationship between classroom climate and student attitude and achievement outcomes, especially for student attitude. An examination of the structure coefficients from the canonical analysis suggested that student outcomes would be better when the students perceive their classrooms as having more Cohesion and less Friction. On the whole, the correlational analyses confirm a consistent and strong relationship between the nature of classroom climate and student outcomes.

Table 6 Simple Correlations (*r*), Multiple Correlations (*R*), Canonical Correlations and Standardised Regression Coefficients (ß) Between MCI and Student Outcomes for Two Units of Analysis

MCI Scale	Unit of Analysis	Simple Correlation, *r*		Standardised Regression Coefficient, ß	
		Liking	Achievement	Liking	Achievement
Cohesion	Individual	0.33 **	0.16 **	0.22 **	0.06 *
	Class Mean	0.72 **	0.55 **	0.22	-0.01
Competition	Individual	-0.12 **	-0.05 **	-0.04	0.03
	Class Mean	-0.32 *	-0.21	-0.12	0.10
Friction	Individual	-0.33 **	-0.28 **	-0.19 **	-0.27 **
	Class Mean	-0.78 **	-0.70 **	-0.37	-0.90 **
Task Orientation	Individual	0.27 **	0.16 **	0.06 *	-0.01
	Class Mean	0.70 **	0.51 **	0.24	-0.19
Multiple Correlation *R*	Individual			0.40 **	0.28 **
	Class Mean			0.81 **	0.71 **
Canonical Correlation	Individual			0.42 **	
	Class Mean			0.84 **	

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

In addition to the series of correlational analyses, a multilevel analysis (a HLM analysis similar to that used for the QTI) was computed to provide additional insight into associations between classroom environment and student outcomes. The results of this multilevel analysis are presented in Table 7, together with a comparison of the results of the multiple linear regression. Table 7 indicates that most of the significant results (except for the two differences highlighted in the following paragraph) from the multiple linear regression and the HLM analyses were similar, as well as consistent in direction for either level of analysis (student or class levels). The three significant coefficients for the dimension of Friction were similar in direction for both types of analyses. The more that students perceived friction in class, the lower were the achievement and attitudes towards mathematics. This was true at either level of analysis for student achievement and at the individual level for student affective outcome. In contrast to Friction, Competition was not significant at either level of analysis for both types of analyses.

Generally, with regard to the associations between classroom climate and the two student outcomes, the multiple regression analysis yielded altogether six significant values as compared to four for the HLM analysis (see Table 7). There were three significant values each for the affective and cognitive outcomes in the multiple regression analysis, whereas there were only two significant coefficients each for the affective and cognitive outcomes in the HLM analysis. The two significant associations in the multiple regression analyses which were not replicated in the HLM analyses were between Cohesion and achievement and between Task Orientation and attitudes, both at the individual level of analysis. The HLM analyses indicated that, in contrast to the multiple regression analyses, student perceptions of classroom Cohesion exerted little impact on mathematics achievement and that Task Orientation does not influence student liking for mathematics.

Table 7 A Comparison of Multiple Linear Regression Coefficients and Hierarchical Linear Model Regression Coefficients for Classroom Climate Scales and Student Outcomes at Two Levels of Analysis (Individual and Class Mean)

MCI Scale	Level of Analysis	Multiple Linear Regression Coefficients		Hierarchical Linear Model Regression Coefficients	
		Liking	Achievement	Liking	Achievement
Cohesion	Individual	0.22 **	0.06 *	0.42**	0.05
	Class Mean	0.22	-0.01	0.10	-0.08
Competition	Individual	-0.04	0.03	-0.09	0.01
	Class Mean	-0.12	0.10	-0.29	0.26
Friction	Individual	-0.19 **	-0.27 **	-0.22**	-0.10**
	Class Mean	-0.37	-0.90 **	-0.34	-1.07**
Task Orientation	Individual	0.06 *	-0.01	0.07	-0.03
	Class Mean	0.24	-0.19	0.41	-0.28

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

The findings from the series of correlational and multilevel analyses discussed above indicated that of the four scales of classroom climate (Cohesion, Competition, Friction and Task Orientation), Friction accounted for the largest amount of variance in student outcomes. It appears that a class that enjoys greater cohesion among its students and sees less friction contributes to a conducive classroom environment that enhances student achievement and attitudes. It is interesting to note that competition appears to have little impact on student outcomes.

Unique and Common Variance Associated with QTI and MCI

In order to examine the magnitude of the amounts of variance in student outcomes explained by the QTI and the MCI, commonality analyses were performed on the data. Commonality analysis is widely used to estimate the unique and confounded components of variance explained in criteria by two or more sets of predictors (Cooley & Lohnes, 1976; Pedhazur, 1982; Fraser, Giddings & McRobbie, 1992a). The uniqueness in this context would be the variance in attitude or achievement attributable to either the QTI or the MCI beyond that attributable to the other instrument. The commonality is the confounded contribution shared by both measures to variance in student outcomes.

Table 8 reports the results of commonality analyses that were computed using the R^2 statistic to examine the unique and common contributions of the QTI and MCI in explaining variance in student outcomes. Data were based on the same sample of 1,512 students in 39 mathematics classes. Separate commonality analyses were performed for each student outcome (Liking and Achievement) and the individual student was used as the unit of statistical analysis.

Table 8 Commonality Analysis of $R2$ for QTI and MCI for Individual as Unit of Analysis

Outcome	$R2$ for Individual Students			
	Uniqueness		Commonality	Total
	QTI	MCI		
Liking	0.13	0.13	0.03	0.29
Achievement	0.08	0.02	0.07	0.17

As for the Liking outcome, the finding that the QTI and the MCI each made a sizeable unique contribution (0.13), and a small common contribution (0.03), to the variance in student Liking scores supports the usefulness of including both the QTI and the MCI within the same study of attitudinal outcomes. In addition, this finding further emphasises that the QTI and the MCI each assesses different aspects of classroom learning environment. The results are presented diagrammatically in Figure 3.

Figure 3 Diagrammatic Representation of Commonality Analysis of R^2 for QTI and MCI for Student Attitude (LMS)

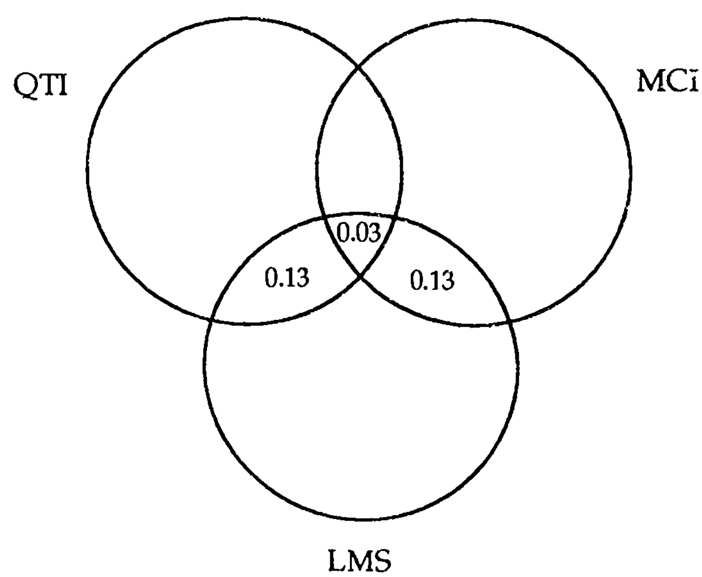
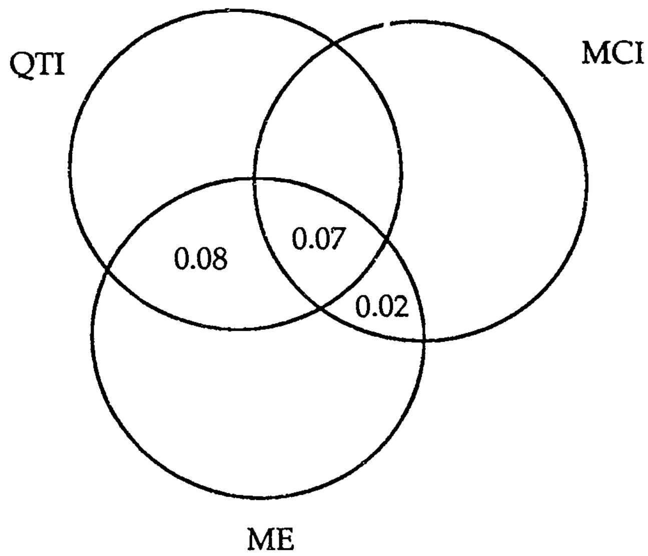


Figure 4 Diagrammatic Representation of Commonality Analysis of R^2 for QTI and MCI for Student Achievement (ME)



With regard to student achievement, the commonality analysis indicated a relatively large common variance (0.07) and that the MCI accounted for little unique variance (0.02) beyond that attributable to the QTI. This suggests that there is little to be gained by including the MCI in a study of achievement that also involves the use of the QTI. Figure 4 presents graphically the unique and common variance associated with the QTI and MCI for student achievement.

Generally the commonality analyses indicated that the values of the uniqueness and the commonality were different for the two student outcomes.

Gender Differences in Student Achievement, Attitudes and Perceptions of Classroom Environment

The data were derived from the same sample of 1,512 students from 39 mathematics classes. A breakdown of the student sample by gender revealed that there were altogether 815 boys and 697 girls. The unit of analysis chosen as appropriate was the within-class mean computed separately for boys and girls. That is, for each class, the boys' mean and the girls' mean were calculated as a matched pair of scores. The unit of analysis, thus, was the within-class gender sub-group. This particular unit of analysis was appropriate for two reasons. Firstly, as one of the research questions involved gender differences in student achievement, attitudes and perceptions of classroom environment, an analysis based on the means of gender groupings was pertinent to the study. Secondly, this unit of analysis avoided the confounding effects, as in some previous studies, of using the individual student as the unit of analysis. That is, if boys and girls were represented disproportionately in different schools, then any differences detected could be explained by differences in school rather than gender per se. This problem was avoided by having each class provide a matched pair of the boys' mean score and the girls' means score.

The first step in analysing the data for gender differences in the 14 dependent variables (the two outcome measures of LMS and ME, eight QTI scales and four MCI scales) was to perform multivariate analysis of variance (MANOVA) for repeated measures. Because each class furnished a matched pair of scores (the boys' mean and the girls' mean), repeated measures analyses were appropriate. As the number of classes was limited (N=39), it was not considered meaningful to include all 14 dependent variables in a single analysis. Therefore, one MANOVA was performed for the two outcome measures and four MCI scales together, and another MANOVA was performed for the eight QTI scales.

For both MANOVAs, the multivariate test yielded significant results ($p<0.05$) in terms of Wilks' lambda criterion. This meant that there were gender differences in the set of criterion variables as a whole in both cases. Because the multivariate F was significant, a t test for dependent samples was conducted and interpreted for each of the 14 individual dependent variables (two outcome measures, eight QTI scales and four MCI scales). The results of the t tests are shown in Table 9.

Table 9 shows that there were no significant gender differences in terms of student attitude towards learning of mathematics. However, there emerged a small but significant gender difference in student achievement (approximately one quarter of a standard deviation), in favour of boys. In addition, girls perceived their teachers' interactional behavior and classroom climate more favourably than boys did, and this is consistent with previous research (Lawrenz, 1987; Fraser, Giddings & McRobbie, 1992a). The girls consistently rated more highly teacher behaviors that have positive connotations (such as Understanding and Helping/Friendly) and lower on interactional behaviors that have negative connotations (such as Uncertain and Admonishing). Girls also held more favourable perceptions of their classroom climate and did not consider their classrooms as competitive as did the boys. The magnitude of significant gender differences on QTI and MCI scales generally was small for it measured approximately half a standard deviation. Overall, the pattern of gender differences in classroom environment was small in magnitude but consistent in direction for all the environment scales.

Table 9 Gender Differences in Student Outcomes and Perceptions of Classroom Environment Using the Within-Class Gender Sub-group as Unit of Analysis

Dependent Variables	Boys		Girls		*t*
	Mean	SD	Mean	SD	
Student Outcomes					
Attitude	26.25	1.77	26.60	1.85	-1.63
Achievement	5.97	1.44	5.57	1.49	3.66*
QTI Scales					
Leadership (DC)	15.48	0.99	15.66	0.86	-1.82
Helping/Friendly (CD)	14.28	1.70	14.80	1.65	-3.73*
Understanding (CS)	13.24	1.44	13.49	1.31	-2.38*
Student Responsibility/ Freedom ((SC)	9.13	0.77	9.14	0.81	-0.08
Uncertain (SO)	7.92	0.80	7.73	0.63	2.28*
Dissatisfied (OS)	9.25	1.61	8.68	1.34	4.93*
Admonishing (OD)	9.50	1.68	9.04	1.48	4.07*
Strict (DO)	13.67	0.91	13.75	0.98	-0.87
MCI Scales					
Cohesion	12.00	0.77	12.02	0.82	-0.17
Competition	10.02	0.57	9.66	0.71	3.31*
Friction	7.45	1.13	7.40	1.15	0.52
Task Orientation	10.59	0.94	10.78	0.94	-1.75

* $p < 0.05$

Conclusion

Because this research broke new ground in terms of being one of the first studies in Singapore in the area of classroom learning environment, one of its important contributions was the modification and validation of two classroom climate instruments. A modified version of the Questionnaire on Teacher Interaction (QTI) was used to assess teacher-student interpersonal behavior whereas an adapted form of the My Class Inventory (MCI) was used to assess classroom environment. Data from the administration of these instruments to 1,512 students in 39 Grade 5 mathematics classes in Singapore confirmed that each scale in each questionnaire exhibited satisfactory internal consistency reliability (with either the student or the class mean as the unit of analysis) and was able to differentiate between the perceptions of students in different classrooms.

In order to explore outcome-environment associations in elementary mathematics classrooms in Singapore, data were subjected to a series of correlational analyses (including simple, multiple and canonical) and multilevel (hierarchical linear model) analyses, using two levels of analysis (the student and the class). The results were similar (in both patterns of significance and the direction of relationships) for the different types of statistical analysis. In particular, better achievement and student attitudes were found in classes with a greater emphasis on teacher Understanding, Helping/Friendly and Leadership behaviors, and also in classes showing more cohesion and less friction. The incorporation of multilevel analysis into classroom environment research is relatively new and potentially beneficial to future research in the field.

In addition, a commonality analysis (using the R^2 statistic for individual as the unit of analysis) was undertaken to examine the magnitude of the variance in student outcomes explained jointly and uniquely by interpersonal teacher behavior and classroom climate. The analysis indicated that the values of the uniqueness and the commonality were different for the two student outcomes (attitudes and achievement).

For the analysis of gender differences in students' achievement, attitudes and perceptions of classroom environment, multivariate analyses of variance (MANOVA) for repeated measures were performed for the measures of outcome and classroom environment. Although there were no differences in the attitude of boys and girls towards mathematics, boys showed better mathematics achievement than did girls. Generally, the pattern of gender differences in perceptions of classroom environment was small in magnitude but consistent in direction for all the environment scales.

Finally, the study showed that no teacher should ignore the development of interactional skills as teaching is immersed in a sea of human interactions. It is imperative for teachers to develop positive teacher-student relationships as this would enhance the development of a conducive classroom climate, especially one that is cohesive and task orientated.

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