LEARNING ENVIRONMENT AND STUDENT OUTCOMES IN PRIMARY MATHEMATICS CLASSROOMS IN SINGAPORE

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Abstract

This study examined two aspects of classroom learning environment (interpersonal teacher behaviour and classroom climate) and their associations with affective and cognitive outcomes among primary mathematics students in Singapore. Also gender differences in students' achievement, attitudes and perceptions of classroom environment were explored. A random sample of 1,512 boys and girls from government primary 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, namely, the individual student and the class mean. For the analysis of gender differences, multivariate analyses of variance for repeated measures were performed for the two outcome measures and the classroom environment scales. The study led to the validation of two widely-applicable and convenient learning environment questionnaires for future use by researchers and teachers at the primary school level. Overall the different methods of analysis yielded consistent associations between classroom environment and student outcomes. Gender differences were detected in mathematics achievement, in favour of boys, but girls generally viewed their classroom environments more favourably than the boys did.

Part 1: Introduction

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 (Berliner, 1983; Brophy, 1988; Doyle, 1986; Galton, 1987; Kounin, 1970; Shulman, 1990). Clearly any thorough analysis of the classroom learning environment must consider the key players involved, namely, the teacher and the students. The collective nature of the classroom has been described in various terms such as 'dynamic', 'complex', 'interactive' and 'interpersonal'. The interplay of the behaviour of both the teacher and the students determines the classroom or psychosocial climate. Classroom practices and developments, particularly during the last 30 years, have indicated that a positive classroom climate is needed for effective learning (Brophy & Putnam, 1979; Emmer, Evertson, & Anderson, 1980).

The concept of a learning environment has taken root since the 1930s, especially with the emergence of Murray's Needs-Press model (1938) and Kurt Lewin's social-psychological climate work (1936) which recognised that behaviour is considered to be a function of the person and the environment. In 1960, a framework for the analysis of the classroom group as a unique social system was developed by Getzels & Thelen (1960). Stern (1970) formulated a theory of person-environment congruence in which complementary combinations of personal needs and environmental press enhance student outcomes. Later, Doyle (1979) proposed that the classroom be viewed 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 behaviour in the classroom.

The Seventy-eighth Yearbook of the National Society for the Study of Education, 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 and Jackson (1967) put it succinctly, "one cannot not communicate" (p. 51).

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 (Fraser, 1986, 1994; Fraser & Walberg, 1991; MacAulay, 1990). 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 behaviour (Creton, Hermans, & Wubbels, 1990; Wubbels, 1993; Wubbels, Brekelmans, & Hermans, 1987) in secondary classrooms. As the behaviour of both teacher and student influence each other mutually, teacher-student interactional behaviour is assumed to be of crucial importance to student learning in the classroom.

In the past decades, there also has been considerable interest in the teaching and learning of mathematics in schools (Forsyth & Spratt, 1980; Fraser & Tobin, 1993; Korbosky, 1989; Romberg, Carpenter, White, & Tisher, 1990). In particular, this research has included studies of gender differences in mathematics classrooms (Ethington, 1990; Fennema & Leder, 1990; Fennema & Peterson, 1985; Kahle & Meece, 1994; Parker, Rennie, & Fraser, in press). Gender differences have been found in mathematics classrooms, including in teacher-student interactions (Eccles & Blumenfeld, 1985; Koehler, 1990) and student achievement (Hanna, 1989; Hensel, 1989), which were two foci in the present study.

Because the data for many educational research studies are derived from students in intact classes, they are inherently hierarchical and could benefit from the use of multilevel analysis (Bock, 1989; Goldstein, 1987; Raudenbush & Bryk, 1989). Despite the potential advantages of this technique in classroom environment research, however, von Saldern (1986) notes that its use virtually has been nonexistent. The main advantage in using multilevel analysis is that it takes cognizance of the multilevel or hierarchical nature of classroom settings. Because ignoring the nested structure of this type of data gives rise to problems of aggregation bias (within-group homogeneity) and imprecision (Raudenbush, 1988), the use of multilevel analysis was considered prudent.

The present study aimed to investigate two aspects of classroom learning environment (interpersonal teacher behaviour and classroom climate) in primary mathematics classes in Singapore. In addition to validating two widely-applicable learning environment instruments for use at the primary level, the study investigated associations between two student outcomes (attitudes and achievement) and student perceptions of interpersonal teacher behaviour and classroom climate. Also gender differences in learning environment perceptions were investigated. Overall this research made the following distinctive contributions to the field of learning environment research:

• Although much research on learning environments has been completed at the secondary school level, this study provides one of the most comprehensive of the relatively small number of studies undertaken at the primary school level.

• This study is one of a small handful that marks the beginning of the field of classroom environment research in Singapore.

• For the first time in any country, a primary version of the Questionnaire on Teacher Interaction (QTI) was developed, validated and used in research applications.

• The My Class Inventory (MCI) was adapted and cross-validated for use in Singapore.

• The study provided one of the first uses of multilevel analysis in learning environment research (and included a comparison of results from using well-established multiple regression techniques).

• By using two learning environment instruments within the same study (the QTI and MCI), it was possible to ascertain the unique and joint contributions of each instrument to student outcomes, therefore providing insights into the usefulness of including both instruments together in future research.

• The research included one of the few investigations of gender differences in students' learning environment perceptions.
In reporting the present study, this paper is organised into the following sections (following the present introductory section):

- Part 2: Review of Research
- Part 3: The Sample
- Part 4: The Instruments
- Part 5: Validation of Instruments
- Part 6: Environment-Outcome Associations
- Part 7: Gender Differences in Perceptions of Classroom Environment
- Part 8: Conclusion and Discussion

**Part 2: Review of Research**

*Field of Learning Environment Research*

Over the previous quarter of a century, considerable interest has been shown internationally in the conceptualisation, measurement and investigation of perceptions of psychosocial characteristics of the learning environment of classrooms at the primary, secondary and higher education levels (Chavez, 1984; Fraser, 1986, 1989; Fraser, 1994; Fraser & Walberg, 1991; Walberg, 1979). Classroom environment instruments have been used as sources of predictor and criterion variables in a variety of research studies. Use of student perceptions of actual classroom environment as predictor variables in several different countries has established consistent relationships between the nature of the classroom environment and various student cognitive and affective outcomes (Fraser, 1986; Fraser & Fisher, 1982; Haertel, Walberg, & Haertel, 1981). Furthermore, research involving a person-environment fit perspective has shown that students achieve better where there is greater congruence between the actual classroom environment and that preferred by students (Fraser & Fisher, 1983).

Studies involving use of the actual form of classroom environment scales as criterion variables have revealed that classroom psychosocial climate varies between different types of schools (Trickett, 1978) and between coeducational and single-sex schools (Trickett, Trickett, Castro, & Schaffner, 1982). Both researchers and teachers have found it useful to employ classroom climate dimensions as process criteria of effectiveness in curriculum evaluation because they have differentiated revealingly between alternative curricula when student outcome measures have shown little sensitivity (Fraser, Williamson, & Tobin, 1987). For example, in an evaluation of an innovation in computer-assisted learning (CAL), it was found that students using CAL perceived their classrooms as having higher levels of gender equity, investigation, innovation and resource adequacy than did a control group (Fraser & Teh, 1994; Teh & Fraser, 1994). Research in the USA (Moos, 1979a), Australia (Fisher & Fraser, 1983), and The Netherlands (Wubbels, Brekelmans, & Hooymayers, 1991) compared students' and teachers' perceptions and found that, first, both students and teachers preferred a more positive classroom environment than that perceived as being actually present and, second, teachers tended to perceive the classroom environment more positively than did their students in the same classrooms. In promising small-scale practical applications, teachers have used assessments of their students' perceptions of their actual and preferred classroom environment as a basis for identification and discussion of actual-preferred discrepancies, followed by a systematic attempt to improve classrooms (Fraser & Fisher, 1986; Thorpe, Burden, & Fraser, 1994).
Some of the exciting recent or current lines of classroom environment research involve (1) developing a new instrument for evaluating the degree to which a classroom is consistent with a constructivist epistemology (Taylor, Dawson, & Fraser, 1995), (2) investigating the links between and the joint influence of classroom, school, family and other environments on student outcomes (Moos, 1991), (3) incorporating classroom environment as one factor in a multi-factor model of educational productivity (Fraser, Walberg, Welch, & Hattie, 1987), (4) exploring ways in which classroom environment instruments can be used to advantage by school psychologists (Burden & Fraser, 1993), (5) incorporating learning environment ideas into teacher education (Fraser, 1993), (6) investigating changes in classroom environment during the transition from primary to high school (Midgley, Eccles, & Feldlaufer, 1991), (7) incorporating the assessment of classroom environment in teacher assessment schemes (Heroman, Loup, Chauvin, & Evans, 1991), (8) the development and application of a new instrument for science laboratory classroom environments (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, in press), and (9) research on the distinctiveness of the learning environment of Catholic schools (Dorman, Fraser, & McRobbie, 1994).

Because the quality of interpersonal interactions between the teacher and students is such an important aspect of the classroom learning environment, Wubbels and Levy (1993) have initiated a major program of research in this area. This work on teacher interpersonal behaviour, which formed an important thrust within the present study in Singapore, is discussed in the next section.

**Teacher Interpersonal Behaviour**

Inspired by the theory of Watzlawick, Beavin and Jackson (1967), a systems approach to communication was adapted to the educational setting to describe teacher behaviour within the classroom setting (Wubbels, Creton, & Holvast, 1988). According to Creton, Wubbels and Hooymayers (1993), systems communication theory is underpinned by the interdependent relationship of circularity and change. Circularity refers to the inter-relatedness of all aspects of the communication system; changes in one aspect affects changes in another (Creton, Wubbels, & Hooymayers, 1993). Therefore, in the case of the classroom setting, the behaviour of the teacher determines and is determined by the behaviour of the students (Creton, Wubbels, & Hooymayers, 1993; Wubbels, Brekelmans, & Hooymayers, 1991).

Leary (1957) developed a model that allows the graphic representation of interpersonal behaviours along two dimensions, influence and proximity, that measure specific interpersonal behaviours. Interpersonal communication can be plotted according to how cooperative or dominant the participant is. Leary's Model uses an influence dimension (Dominance, D — Submission, S) to measure the degree of dominance or control over the communication process and a proximity dimension (Cooperation, C — Opposition, S) to measure the degree of affinity or cooperation felt by those involved in the communication process.

Leary's Model was adapted by Wubbels, Creton and Hooymayers (1985) to form a model for interpersonal teacher behaviour (Wubbels, Brekelmans, & Hooymayers, 1991; Wubbels, Creton, Levy, & Hooymayers, 1993; Wubbels, & Levy, 1993). This model uses the same axes of proximity and influence as Leary's model and describes the types of interpersonal behaviours displayed by teachers (See Figure 1).

The model for interpersonal teacher behaviour has eight sectors, each describing different facets of teacher behaviour: Leadership (DC); Helping/Friendly (CD); Understanding (CS); Student Responsibility/Freedom (SC); Uncertain (SO); Dissatisfied (OS); Admonishing (OD); and Strict (DO) behaviour. By using this model, each instance of teacher behaviour can be placed within the eight sectors (Wubbels, Brekelmans, & Hooymayers, 1991; Wubbels, 1993). Figure 1 provides examples of typical teacher behaviours for each sector, which is labelled according to its coordinate position (DO, DC, CD, etc.). For example, the sectors SC and CS are both characterised by Cooperation and
Submission. A teacher plotted in the SC sector, where the presence of Submission predominates over the presence of Cooperation, would be more likely to provide students with responsibility and take a role that allows students more freedom. This would be evident during a lesson that was student guided, such as the use of learning centres. The CS sector, however, would describe a teacher with more cooperation and less submission. This teacher would be seen as understanding and able to empathise with students.

Based on his Model of Interpersonal Behaviour, Leary developed an instrument, the Interpersonal Adjective Checklist, that could be used to measure behaviours. This has been used extensively in psychotherapy and the management of behaviour, but proved inappropriate for the measurement of interpersonal teacher behaviour (Wubbels, Creton, Levy, & Hooymayers, 1993). It was from this checklist, however, that Wubbels and his colleagues developed the **Questionnaire on Teacher Interaction (QTI)** to examine interpersonal teacher behaviours through students’ perceptions (Wubbels, Brekelmans, & Hooymayers, 1991; Wubbels, Creton, & Hooymayers, 1985). The QTI consists of eight scales, corresponding to the eight sectors of the Model for Interpersonal Teacher Behaviour in Figure 1.

FIGURE 1. Model of Interpersonal Teacher Behaviour

![Diagram of the Model of Interpersonal Teacher Behaviour]

The original Dutch version of the QTI incorporated about 10 items in each scale, with a total of 77 items (Wubbels, Creton, Levy, & Hooymayers, 1993). An English-language version of the QTI was developed in the late 1980s (Wubbels, & Levy, 1991), incorporating eight items for each scale (a total of 64 items), and administered in the USA. Both
questionnaires were developed for educational research purposes in secondary schools and used a five-point Likert response format. Subsequently, the QTI also has been used in studies in Israel (Kremer-Rayon & Wubbels, 1992) and Australia (Fisher, Fraser, & Wubbels, 1993; Fisher, Fraser, & Henderson, 1995; Fisher, Henderson, & Fraser, 1995; Kent, Fisher, & Fraser, 1995; Wubbels, 1993). Wubbels developed a short version, in English, of the QTI to enable secondary school teachers to obtain feedback on their own interpersonal relationships within the classroom (Wubbels, 1993). This version consists of 48 items with six items for each scale.

**Past Research in Singapore**

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 computer-assisted classroom environments (Fraser & Teh, 1994; Teh & Fraser, 1994). This study led to the development and validation of a new instrument for learning environment research in computer-assisted instructional settings. It also established that computer-assisted learning for below-average secondary students was a more efficacious instructional method than a traditional teaching method. Furthermore, an investigation of associations between student outcomes and computer-assisted learning environments 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 used the *Individualised Classroom Environment Questionnaire* (ICEQ) in exploring secondary students' perceptions of their classroom climate in different types of schools, streams and subject specialisations (Lim, 1993). The study indicated, among other things, that students preferred a more positive classroom environment than actually was present.

Wong and Fraser's (1994) recent study focused on determinants and effects of chemistry laboratory classroom environments 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 in their preferred (but not their actual) perceptions. Also relationships were found between student affective outcome and the perceived environment of chemistry laboratories, and gender differences in perceptions emerged.

A small-scale study in one primary school (Ong, 1987) investigated relationships between classroom management practices and classroom environment.

As practically all past studies in Singapore have been undertaken in secondary classrooms, it was timely to initiate the present study focusing on interpersonal teacher behaviour and classroom climate at the primary level. Therefore, it was appropriate 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 (Kaur, 1992; Ministry of Education, 1988). Despite the paucity of research in this area, it is evident that a gender gap exists in mathematics achievement among Singaporean students (Kaur, 1992). Although currently, considerable educational research in Singapore has focused on issues and problems relating to secondary schools, less research work has been done concerning primary schools, as is the case also in developed western countries (Raviv, Raviv, & Reisel, 1990).

The 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 learning environment and its association with student learning. 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 these students are more mature and at a higher stage of psychological development than students at lower grade levels, students at the grade 5 level (aged 11–12 years) are more capable of making decisions or evaluations regarding the competencies and behaviours of their teachers and other classroom events. The grade 5 level also occurs just before the final year of primary 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 years of primary school education in Singapore. With the increasing emphasis on educational excellence, it is even more desirable to study developments, practices and issues affecting primary schools in Singapore.

In the Singapore primary 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 primary 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 especially 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 the grade 3 level (about nine years of age), girls achieved better than boys in mathematics, while the situation was reversed in favour of boys at the Primary School Leaving Examination level (i.e., at the grade 6 level when students are about 12 years old). In view of the importance of mathematics in the school curriculum; it was both timely and beneficial to focus the present study on whether the teacher-student-context triad promotes or hinders student liking for mathematics and student achievement in primary schools in Singapore. Therefore, an aspect of this study of the mathematics classroom environment was how teacher-student relationships and classroom climate affect grade 5 students' cognitive and affective outcomes.

Part 3: The Sample

A random sample of 39 mathematics classes from 13 government coeducational primary 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 students 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.

Part 4: The Instruments

The four instruments used in this study of learning environment in primary mathematics classroom were the Questionnaire on Teacher Interaction (Primary), the My Class Inventory, the Liking Mathematics Scale, and the Mathematics Exercise. These instruments are discussed in turn below.

Questionnaire on Teacher Interaction (Primary)

A new primary 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 (64 items) used in an Australian study; and the short form QTI (48 items) designed for Australian teachers to obtain feedback from their classes (Wubbels, 1993). The present study involved further adaptation of the QTI to make it suitable for use at the primary level, and its subsequent validation in Singapore. For example, the item "The teacher takes a personal interest in us" was changed to "The teacher cares about us". The 48-item QTI (Primary) assesses the eight dimensions of teacher behaviour described in Figure 1.

For instance, Figure 1 illustrates what Leadership behaviour encompasses by stating typical teacher behaviours which include "notice what's happening, lead, organise, give orders, set tasks, determine procedure, structure the classroom situation, explain and hold attention". Table 1 provides a description and sample item for each scale in the primary version of the QTI.

Appendix A contains a complete copy of the QTI (Primary). Items are arranged in cyclic order so that the first, second, third, fourth, fifth, sixth, seventh and eighth item in each group of eight items assesses, respectively, Leadership, Helping/Friendly, Understanding, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict behaviour. Items are scored 1, 2 and 3, respectively, for the responses Seldom, Sometimes and Most of the Time. Omitted or invalid items are scored 2.

My Class Inventory

Classroom climate in the present study was assessed with a modified version of the My Class Inventory (MCI; Fisher & Fraser, 1981; Fraser & O'Brien, 1985). This 20-item version provides information regarding student perceptions of the four classroom climate scales of Cohesion, Competition, Friction and Task Orientation. Descriptive information for the MCI is provided in Table 1.

A copy of the MCI is provided in Appendix B. Items are arranged in cyclic order so that the first, second, third and fourth item in each group of four items assesses, respectively, Cohesion, Competition, Friction and Task Orientation. Items with their item numbers underlined are scored 3, 2, and 1, respectively, for the responses Seldom, Sometimes and Most of the Time. All other items are scored in the reserve manner. Omitted or invalid responses are scored 3. Scores for each scale can be obtained by adding the score obtained for each of the five items in each of the scales. For example, the sum of the scores for items 1, 5, 9, 13 and 17 represents the scale score for Cohesion, while the total score for items 2, 6, 10, 14 and 18 represents the scale score for Competition. The higher the scale score, the more a class would demonstrate that particular dimension of the classroom climate.

Affective and Cognitive Outcome Measures

The affective outcome was assessed with the Liking Mathematics Scale (LMS), which 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). The LMS comprises 10 statements which are expressed in a simple, direct and concise manner, such as "I enjoy mathematics classes" and "Mathematics is fun".

For the QTI (Primary), the MCI and the LMS, students respond on a three-point Likert scale consisting of Seldom, Sometimes and Most of the Time.

Student cognitive achievement was assessed with a 10-item mathematics achievement test, the Mathematics Exercise (ME), which was based on 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). Items in the ME were developed after a careful examination of the grade 5
mathematics syllabus for Singapore primary schools and samples of mathematics assessments (class tests or continuous assessments). The 10 items in the ME were developed after a thorough examination of the mathematics syllabi for grades 4 and 5. Each item was designed with a problem/situation as the stem, and had four alternative responses.

**TABLE 1. Descriptive Information for QTI and MCI Scales**

<table>
<thead>
<tr>
<th>Scale Name</th>
<th>Description</th>
<th>Sample Item</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Questionnaire on Teacher Interaction (QTI)</strong></td>
<td>The degree to which:</td>
<td></td>
</tr>
<tr>
<td>Leadership (DC)</td>
<td>... the teacher provides leadership to the class and holds student attention.</td>
<td>We all listen to this teacher.</td>
</tr>
<tr>
<td>Helping/Friendly (CD)</td>
<td>... the teacher is friendly and helpful towards students.</td>
<td>This teacher is friendly.</td>
</tr>
<tr>
<td>Understanding (CS)</td>
<td>... the teacher shows understanding/concern/care for students.</td>
<td>This teacher trusts us.</td>
</tr>
<tr>
<td>Student Responsibility/Freedom (SC)</td>
<td>... students are given opportunities to assume responsibility for their own activities.</td>
<td>This teacher gives us a lot of free time in class.</td>
</tr>
<tr>
<td>Uncertain (SO)</td>
<td>... the teacher exhibits his/her uncertainty.</td>
<td>This teacher doesn’t seem sure.</td>
</tr>
<tr>
<td>Dissatisfied (OS)</td>
<td>... the teacher shows unhappiness/dissatisfaction with students.</td>
<td>This teacher is unhappy.</td>
</tr>
<tr>
<td>Admonishing (OD)</td>
<td>... the teacher shows anger/temper/impatience in class.</td>
<td>This teacher gets angry quickly.</td>
</tr>
<tr>
<td>Strict (DO)</td>
<td>... the teacher is strict with and demanding of students.</td>
<td>This teacher is strict.</td>
</tr>
</tbody>
</table>

| **My Class Inventory (MCI)**        | The degree to which:                          |                                |
| Cohesion                            | ... students feel a sense of belonging.       | Children in our class like each other as friends. |
| Competition                         | ... students compete with classmates.         | We race to see who can finish first. |
| Friction                            | ... students do not get along and are unfriendly to one another.              | Some pupils fight in my class. |
| Task Orientation                    | ... students are orderly and complete work on time.                           | All the pupils in my class hand in their work on time. |

Items are scored 1 for Seldom, 2 for Sometimes, and 3 for Most of the Time.
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 to gather subjective information to guide smooth administration of instruments 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, (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. The response format in the questionnaires 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.

Although the present pioneering study involved extensive use of quantitative methods, the qualitative methods used in the pilot study are considered to form a most important part of the overall study. Moreover, now that the present initial study has used quantitative methods to validate widely-applicable instruments for future use, it is highly desirable to combine qualitative and quantitative methods in future research with these instruments as recommended by Fraser and Tobin (1991).

Data Collection

One of the researchers personally administered the four instruments in every class involved in the 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 (Primary) and, after a short rest, responded to the MCI, LMS and ME. Each instrument was printed on paper of a different colour to aid administration and add variety to the process.

Part 5: Validation of Instruments

Questionnaire on Teacher Interaction (QTI)

Data for the Singapore sample were analysed to furnish evidence for the QTI regarding scale internal consistency reliability, pattern of scale intercorrelations, and ability of each scale to differentiate between classrooms. The Cronbach alpha coefficient was computed for each QTI scale as a measure of internal consistency reliability at two levels of analysis, namely, the individual student score (N=1,512) and the class mean score (N=39). Table 2 suggests 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 with the individual student as the level of analysis. As expected, the reliability estimates were higher when the class mean was used as the unit of analysis. These values for a Singaporean sample 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 behaviour and the lowest for Student Responsibility/Freedom behaviour. Overall data in Table 2 suggest that the
QTI (Primary) has comparatively high reliability, especially for short scales containing only six items each.

Further evidence regarding the validity of the primary version of the QTI was obtained by examining the scale intercorrelation matrix for two units of analysis (the individual student and the class mean). According to the circumplex model described in Figure 1, adjacent scales (for example, Helping/Friendly, CD, and Understanding, CS), should correlate most highly 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 (Wubbels & Levy, 1993). Diametrically opposite scales, such as Helping/Friendly (CD) and Dissatisfied (OS), should have the highest negative correlation (Wubbels, 1993). Overall, the QTI scale intercorrelations satisfied this assumption with minor discrepancies. For example, this characteristic assumption of the circumplex model of interpersonal teacher behaviour can be illustrated with the Helping/Friendly (CD) scale's correlations with its adjacent and opposite scales (see Figure 2). At the class level of analysis, Figure 2 shows that adjacent scales of Leadership (DC) and Understanding (CS) correlate highest and positively with Helping/Friendly (CD), with values of 0.90 and 0.91, respectively. This correlation became smaller for scales located further from each other, and the directly opposite scale of Dissatisfied (OS) had the highest negative correlation of -0.90 with Helping/Friendly.

** TABLE 2. Internal Consistency Reliability (Cronbach Alpha Coefficient) for Two Units of Analysis and Ability to Differentiate between Classrooms (ANOVA Results) for the QTI (Primary)**

<table>
<thead>
<tr>
<th>QTI Scale</th>
<th>Alpha Reliability</th>
<th>ANOVA Eta²</th>
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<tbody>
<tr>
<td></td>
<td>Individual N=1,512</td>
<td>Class Mean N=39</td>
</tr>
<tr>
<td>Leadership (DC)</td>
<td>0.63</td>
<td>0.90</td>
</tr>
<tr>
<td>Helping/Friendly (CD)</td>
<td>0.78</td>
<td>0.96</td>
</tr>
<tr>
<td>Understanding (CS)</td>
<td>0.65</td>
<td>0.94</td>
</tr>
<tr>
<td>Student Responsibility/Freedom (SC)</td>
<td>0.58</td>
<td>0.73</td>
</tr>
<tr>
<td>Uncertain (SO)</td>
<td>0.50</td>
<td>0.83</td>
</tr>
<tr>
<td>Dissatisfied (OS)</td>
<td>0.76</td>
<td>0.96</td>
</tr>
<tr>
<td>Admonishing (OD)</td>
<td>0.74</td>
<td>0.93</td>
</tr>
<tr>
<td>Strict (DO)</td>
<td>0.58</td>
<td>0.81</td>
</tr>
</tbody>
</table>

** p<0.01
The $\eta^2$ (the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.
Another desirable characteristic of a classroom environment scale is that students within a class see their classroom environment relatively similarly, and that average class perceptions 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 QTI scale between the perceptions of students in different classes. The $\eta^2$ statistic, which represents the amount of variance in interpersonal teacher behaviour scores accounted for by class membership, ranged from 0.13 to 0.38 (Table 2).

**My Class Inventory**

The modified version of the MCI was administered to the same sample which responded to the QTI during mathematics curriculum time and in the absence of the mathematics teachers, in order to ensure that student responses would not be inhibited in any way by the presence of the teacher. 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.

Table 3 reports the internal consistency of the MCI at two levels of analysis. 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 at the class level, which are higher than those reported in Fraser, Malone and Neal (1989). 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 MCI

<table>
<thead>
<tr>
<th>MCI Scale</th>
<th>Alpha Reliability</th>
<th>Mean Correlation with Other Scales</th>
<th>ANOVA Eta²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Individual N=1,512</td>
<td>Class Mean N=39</td>
<td>Individual N=1,512</td>
</tr>
<tr>
<td>Cohesion</td>
<td>0.73</td>
<td>0.92</td>
<td>0.32</td>
</tr>
<tr>
<td>Competition</td>
<td>0.56</td>
<td>0.75</td>
<td>0.31</td>
</tr>
<tr>
<td>Friction</td>
<td>0.75</td>
<td>0.94</td>
<td>0.42</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>0.68</td>
<td>0.92</td>
<td>0.39</td>
</tr>
</tbody>
</table>

**p < 0.01

The Eta² (the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

Data concerning discriminant validity were obtained using the mean correlation of a scale with the other three scales of the MCI as a convenient index (see 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 classroom climate.

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. The Eta² statistics, which provides an estimate of the amount of variance in classroom climate scores attributable to class membership, ranged from 0.07 to 0.24 (see Table 3).

Overall, the data presented in Table 3 for the Singaporean sample suggest that the MCI displayed satisfactory reliability and discriminant validity at two levels of analysis and was able to differentiate among the perceptions of students in different classrooms.

Part 6: Environment-Outcome Associations

The main purpose of this study was to examine associations between two aspects of classroom environment (interpersonal teacher behaviour 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 the student and the class as two levels of analysis. In addition, a commonality analysis was undertaken to examine the joint and unique contributions of interpersonal teacher behaviour and classroom climate to variance in student outcomes.
Simple, Multiple and Canonical Correlation Analyses Involving the QTI and Student Outcomes

Table 4 presents for the QTI the results of simple, multiple and canonical correlation analyses separately for the two student outcomes (Liking and Achievement). Using both the student and class levels of analysis, the present findings generally replicate past research into associations between interpersonal teacher behaviour and student learning (Fisher, Henderson, & Fraser, 1995; Wubbels, 1993; Wubbels & Levy, 1993).

TABLE 4. Simple Correlations (r), Multiple Correlations (R), Canonical Correlations and Standardised Regression Coefficients (β) for QTI Scales and Two Student Outcomes for Two Units of Analysis

<table>
<thead>
<tr>
<th>QTI Scale</th>
<th>Unit of Analysis</th>
<th>Simple Correlation, r</th>
<th>Standardised Regression Coefficient, β</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Liking</td>
<td>Achievement</td>
</tr>
<tr>
<td>Leadership (DC)</td>
<td>Individual</td>
<td>0.41**</td>
<td>0.28**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.80**</td>
<td>0.68**</td>
</tr>
<tr>
<td>Helping/Friendly (CD)</td>
<td>Individual</td>
<td>0.43**</td>
<td>0.25**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.80**</td>
<td>0.51**</td>
</tr>
<tr>
<td>Understanding (CS)</td>
<td>Individual</td>
<td>0.36**</td>
<td>0.30**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.81**</td>
<td>0.61**</td>
</tr>
<tr>
<td>Student Responsibility/Freedom (SC)</td>
<td>Individual</td>
<td>0.01</td>
<td>0.07*</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.44**</td>
<td>0.32</td>
</tr>
<tr>
<td>Uncertain (SO)</td>
<td>Individual</td>
<td>-0.28**</td>
<td>-0.28**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.77**</td>
<td>-0.75**</td>
</tr>
<tr>
<td>Dissatisfied (OS)</td>
<td>Individual</td>
<td>-0.38**</td>
<td>-0.25**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.76**</td>
<td>-0.59**</td>
</tr>
<tr>
<td>Admonishing (OD)</td>
<td>Individual</td>
<td>-0.37**</td>
<td>-0.23**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.74**</td>
<td>-0.52**</td>
</tr>
<tr>
<td>Strict (DO)</td>
<td>Individual</td>
<td>-0.02</td>
<td>-0.00</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.30</td>
<td>-0.15</td>
</tr>
<tr>
<td>Multiple Correlation, R</td>
<td>Individual</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canonical Correlation</td>
<td>Individual</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05
** p < 0.01

The first type of correlational analysis reported in Table 4 involved the simple correlation between each outcome and each QTI scale. The major advantage of this analysis is that it furnishes information to educators interested in associations between a particular teacher interpersonal behaviour and a particular outcome. The number of significant simple
correlations ($p<0.01$) in Table 4 is 13 with the individual as the unit of analysis and also 13 with the class as the unit of analysis (16 times that experienced by chance). With the exception of Strict behaviour, generally the simple correlational analysis suggests that the other behaviours all are related to student attitudes and achievement.

The second type of correlational analysis consisted of a multiple regression involving the set of eight QTI scales performed separately for the two student outcomes and for two levels of analysis (Table 4). Relative to the simple correlational analysis, the multiple regression analysis provides a more parsimonious picture of the joint influence of correlated teacher interpersonal behaviour dimension outcomes and reduce the Type I error rate. The multiple correlation was statistically significant ($p<0.01$) for both units of analysis for both outcomes, with the magnitude being 0.89 for the attitude outcome and 0.82 for the achievement outcome at the class level of analysis (Table 4).

In order to interpret which teacher behaviour dimension was making the largest contribution to explaining variance in learning outcomes, the standardised regression coefficients ($\beta$) in Table 4 were examined. The tests of significance for the ($\beta$) weights indicate which individual QTI scales are related significantly to an outcome when the other seven QTI scales are mutually controlled. Although the number of significant results for the multiple regression analysis (14) was smaller than for the simple correlational analysis, again Strict behaviour was the only QTI scale that was not related significantly to either outcome for either unit of analysis.

Although the use of multiple regression analysis overcomes the problem of relationships among QTI scales, relationships between the two outcome measure still could give rise to an inflated Type I error rate for the study as a whole. Canonical analysis can provide a parsimonious picture of relationships between a set of correlated learning outcomes and a set of correlated teacher behaviour variables. The bottom row shows that one significant canonical correlation ($p<0.01$) of 0.54 emerged for the analysis at the student level and a canonical correlation of 0.92 emerged at the class level.

To interpret the results of the canonical analysis, we examined the magnitudes and signs of the structure coefficients (i.e., the simple correlations between a canonical variate and its constituent variables). Substantive interpretations were based on structure coefficients in preference to canonical weights because the latter can be misleading because of redundancy and suppression effects (Cooley & Lohnes, 1976). The overall conclusion from the canonical analysis was that achievement and especially attitudes were linked with greater levels of teacher Leadership, Helping/Friendly and Understanding behaviours.

**Multilevel Analyses Involving the QTI and Student Outcomes**

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 (Goh, 1994; Goh, Young, & Fraser, in press). The Hierarchical Linear Model (HLM) provides an integrated strategy for handling problems such as aggregation bias in standard error estimates and erroneous probability values in hypothesis testing of school effects (Bryk & Raudenbush, 1988; Bock, 1989; Goldstein, 1987; Young & Fraser, 1993). The use of the HLM in investigating the influence of the organisational structure of the school on student performance has been reported by Bryk and Raudenbush (1989, pp. 159-204), Lee and Bryk (1989) and Raudenbush and Bryk (1989).

For this study, HLM2L (Bryk, Raudenbush, Seltzer, & Congdon, 1989) was selected as the computer package most suited to analyse the Singapore data set, and the following equation was used for student attitude towards mathematics as the outcome measure:
MathAtt\textsubscript{ij} = \beta_{0j} + \beta_{1j} \text{Leadership}_{ij} + \beta_{2j} \text{Helping}_{ij} + \beta_{3j} \text{Understanding}_{ij} + \\
\beta_{4j} \text{Responsibility}_{ij} + \beta_{5j} \text{Uncertain}_{ij} + \beta_{6j} \text{Dissatisfied}_{ij} + \beta_{7j} \text{Admonishing}_{ij} + \\
\beta_{8j} \text{Strict}_{ij} + r_{ij}

\beta_{0j} = \gamma_{00} + \gamma_{01} \text{Cohesion}_{ij} + \gamma_{02} \text{Competition}_{ij} + \gamma_{03} \text{Friction}_{ij} + \gamma_{04} \text{Task}_{ij} + \\
\gamma_{05} \text{Uncertain}_{ij} + \gamma_{06} \text{Dissatisfied}_{ij} + \gamma_{07} \text{Admonishing}_{ij} + \gamma_{08} \text{Strict}_{ij} + \mu_{0j}

\beta_{1j} = \gamma_{10}
\beta_{2j} = \gamma_{20}
\beta_{3j} = \gamma_{30}
\beta_{4j} = \gamma_{40}
\beta_{5j} = \gamma_{50}
\beta_{6j} = \gamma_{60}
\beta_{7j} = \gamma_{70}
\beta_{8j} = \gamma_{80}

The random intercept and fixed slopes are described as follows:

\textbf{\beta_{0j}} \quad \text{is the mean student attitude to mathematics in class } j \text{ after controlling for student differences in perceptions of classroom climate between classes;}

\textbf{\beta_{1j}} \quad \text{is the fixed effect of student-perceived teacher Leadership behaviour on attitude towards mathematics in class } j;\n
\textbf{\beta_{2j}} \quad \text{is the fixed effect of student-perceived teacher Helping/friendly behaviour on attitude towards mathematics in class } j;\n
\textbf{\beta_{3j}} \quad \text{is the fixed effect of student-perceived teacher Understanding behaviour on attitude towards mathematics in class } j;\n
\textbf{\beta_{4j}} \quad \text{is the fixed effect of student-perceived teacher Student Responsibility/Freedom behaviour on attitude towards mathematics in class } j;\n
\textbf{\beta_{5j}} \quad \text{is the fixed effect of student-perceived teacher Uncertain behaviour on attitude towards mathematics in class } j;\n
\textbf{\beta_{6j}} \quad \text{is the fixed effect of student-perceived teacher Dissatisfied behaviour on attitude towards mathematics in class } j;\n
\textbf{\beta_{7j}} \quad \text{is the fixed effect of student-perceived teacher Admonishing behaviour on attitude towards mathematics in class } j;\n
\textbf{\beta_{8j}} \quad \text{is the fixed effect of student-perceived teacher Strict behaviour on attitude towards mathematics in class } j.

A similar equation was used with mathematics achievement as the outcome measure.

In the above equation, the eight predictors investigated at the student level of analysis were student perceptions of the eight QTI dimensions. At the classroom level of analysis, these eight predictors were aggregated and investigated for their influence on student
outcomes. These predictors reflected the peer effect of interpersonal teacher behaviour on individual mathematics attitude and achievement.

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. This table 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 four predictors of student outcomes for both levels of analysis (student or class levels). These four predictors are Leadership, Student Responsibility/Freedom, Dissatisfied and Strict teacher behaviours. Different patterns of statistical significance emerged for Helping/Friendly, Understanding, Uncertain and Admonishing behaviours, depending on the level of analysis. Strict teacher behaviour consistently showed a nonsignificant linkage to student outcomes 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 QTI Scales and Two Student Outcomes for Two Levels of Analysis**

<table>
<thead>
<tr>
<th>QTI Scale</th>
<th>Unit of Analysis</th>
<th>Multiple Linear Regression Coefficients</th>
<th>Hierarchical Linear Model Regression Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Liking</td>
<td>Achievement</td>
</tr>
<tr>
<td>Leadership (DC)</td>
<td>Individual</td>
<td>0.15*</td>
<td>0.10*</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.17</td>
<td>0.65</td>
</tr>
<tr>
<td>Helping/Friendly (CD)</td>
<td>Individual</td>
<td>0.20*</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.57*</td>
<td>-0.61</td>
</tr>
<tr>
<td>Understanding (CS)</td>
<td>Individual</td>
<td>0.07*</td>
<td>0.17*</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.40*</td>
<td>0.09</td>
</tr>
<tr>
<td>Student Responsibility/Freedom (SC)</td>
<td>Individual</td>
<td>0.07*</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.00</td>
<td>0.18</td>
</tr>
<tr>
<td>Uncertain (SO)</td>
<td>Individual</td>
<td>-0.07*</td>
<td>-0.20*</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.51*</td>
<td>-0.59*</td>
</tr>
<tr>
<td>Dissatisfied (OS)</td>
<td>Individual</td>
<td>-0.10*</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.47</td>
<td>-0.37</td>
</tr>
<tr>
<td>Admonishing (OD)</td>
<td>Individual</td>
<td>-0.07*</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.14</td>
<td>0.52</td>
</tr>
<tr>
<td>Strict (DO)</td>
<td>Individual</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.05</td>
<td>-0.20</td>
</tr>
</tbody>
</table>

* p<0.05

With regard to the overall picture detected from the multiple regression and HLM analyses concerning associations between teacher behaviour and the two student outcomes, the multiple regression analysis (also reported previously in Table 5) 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 behaviour scales) in the multiple regression analysis that were not replicated in the multilevel analysis pertained
only to associations between teacher behaviour and student attitude. It is interesting to note that, in terms of the inter-relationships between teacher behaviours and student achievement, the same four significant results were obtained for the HLM and multiple regression analyses (Leadership behaviour at the individual student level, Understanding behaviour at the individual level, and Uncertain behaviour at both levels of analysis).

For the student affective outcome, five significant values in the multiple regression analysis were not replicated in the HLM analysis. The main difference revealed in Table 5 pertained to the teacher behaviour 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, although the multiple linear regression indicated a significant association at both levels. The second difference occurred for the relationship between Helping/Friendly teacher behaviour and the student affective outcome at the class level of analysis. In contrast to the multiple regression results, the HLM analysis showed no significant relationship at the class level between teacher Helping/Friendly behaviour and student liking for mathematics. The third difference concerned the negative relationship between teacher Uncertain behaviour 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 behaviour 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 behaviour that were associated with student learning are greater Leadership, Helping/Friendly and Understanding teacher behaviours, and less Uncertain and Dissatisfied teacher behaviour. Because these teacher behaviours foster positive student attitudes towards mathematics learning and/or higher achievement scores, it is desirable for primary mathematics teachers in Singapore to cultivate consciously these positive behaviours and exhibit them more often in their interactions with students, and to refrain from demonstrating negative behaviours (Uncertain and Dissatisfied) in classroom interactions.

Generally, Admonishing and Strict teacher behaviour did not seem to influence either student attitudes towards learning of mathematics or student achievement in the HLM analysis. Teachers, thus, need not feel anxious about undesirable side effects associated with being either too strict or not strict enough with students.

Simple, Multiple and Canonical Correlation Analyses Involving MCI and Student Outcomes

Using simple, multiple and canonical correlation analysis methods identical to those used are for the QTI (see Table 4), data obtained from the MCI, the LMS and the ME were analysed for two units of analysis and are presented in Table 6. As in the case of associations between interpersonal teacher behaviour and student outcomes discussed previously, there was a strong relationship between classroom learning environment and student attitude and achievement outcomes, especially for student attitude. For the simple correlational analysis, all 8 correlations were significant at the student level and 7 were significant at the class level (p<0.05). In the more conservative multiple regression analyses, student attitudes were related to more classroom Cohesion, less Friction and more Task Orientation when other MCI scales were mutually controlled (individual level of analysis only). Achievement was related positively to Cohesion at the individual unit of analysis and negatively to friction at both units of analysis when other MCI scales were mutually controlled. 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 the consistent and strong relationship between
the nature of classroom climate and student outcomes found in past research (Fraser & Fisher, 1982; McRobbie & Fraser, 1993).

Multilevel Analyses Involving MCI and Student Outcomes

In addition to the series of correlational analyses, a multilevel analysis (a HLM analysis similar to that used for the QTI and reported in Table 5) 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 the student affective outcome. In contrast to Friction, Competition consistently was not significantly associated with either outcome at either level of analysis and for both types of analysis.

TABLE 6. Simple Correlations (r), Multiple Correlations (R), Canonical Correlations and Standardised Regression Coefficients (B) for MCI Scales and Two Student Outcomes for Two Units of Analysis

<table>
<thead>
<tr>
<th>MCI Scale</th>
<th>Unit of Analysis</th>
<th>Simple Correlation, r</th>
<th>Standardised Regression Coefficient, B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liking</td>
<td>Achievement</td>
<td>Liking</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Achievement</td>
</tr>
<tr>
<td>Cohesion</td>
<td>Individual</td>
<td>0.33**</td>
<td>0.16**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.72**</td>
<td>0.55**</td>
</tr>
<tr>
<td>Competition</td>
<td>Individual</td>
<td>-0.12**</td>
<td>-0.05**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.32*</td>
<td>-0.21</td>
</tr>
<tr>
<td>Friction</td>
<td>Individual</td>
<td>-0.33**</td>
<td>-0.28**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.78**</td>
<td>-0.70**</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>Individual</td>
<td>0.27**</td>
<td>0.16**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.70**</td>
<td>0.51**</td>
</tr>
<tr>
<td>Multiple Correlation</td>
<td>Individual</td>
<td>0.40**</td>
<td>0.28**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.81**</td>
<td>0.71**</td>
</tr>
<tr>
<td>Canonical Correlation</td>
<td>Individual</td>
<td>0.42**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.84**</td>
<td></td>
</tr>
</tbody>
</table>

* p <0.05
** p <0.01
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 MCI Scales and Two Student Outcomes for Two Levels of Analysis

<table>
<thead>
<tr>
<th>MCI Scale</th>
<th>Level of Analysis</th>
<th>Multiple Linear Regression Coefficients</th>
<th>Hierarchical Linear Model Regression Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Liking</td>
<td>Achievement</td>
</tr>
<tr>
<td>Cohesion</td>
<td>Individual</td>
<td>0.22**</td>
<td>0.06*</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.22</td>
<td>-0.01</td>
</tr>
<tr>
<td>Competition</td>
<td>Individual</td>
<td>-0.04</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.12</td>
<td>0.10</td>
</tr>
<tr>
<td>Friction</td>
<td>Individual</td>
<td>-0.19**</td>
<td>-0.27**</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>-0.37</td>
<td>-0.90**</td>
</tr>
<tr>
<td>Task Orientation</td>
<td>Individual</td>
<td>0.06*</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>Class Mean</td>
<td>0.24</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

* 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 scales (Cohesion, Competition, Friction and Task Orientation), Friction (negative) and Cohesion (positive) accounted for the largest amount of variance in student outcomes. It appears that a class with greater cohesion among its students and less friction has a conducive classroom environment that enhances student achievement and attitudes. It is interesting to note that Competition had a less strong but consistently negative association with student outcomes, especially attitudes.

Commonality Analysis of Unique and Common Variance in Student Outcomes 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; Fraser, Giddings, & McRobbie, 1995; Pedhazur, 1982). 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 $R^2$ Statistic for QTI and MCI for Individual as Unit of Analysis**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>$R^2$ for Individual Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uniqueness</td>
</tr>
<tr>
<td></td>
<td>QTI</td>
</tr>
<tr>
<td>Liking</td>
<td>0.13</td>
</tr>
<tr>
<td>Achievement</td>
<td>0.08</td>
</tr>
</tbody>
</table>

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 $R^2$ Statistic for QTI and MCI for Student Attitude Outcome**
With regard to student achievement, the commonality analysis reported in Table 8 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.

Part 7: Gender Differences in Perceptions of Classroom Environment

For the investigation of gender differences, the same sample of 1,512 students from 39 mathematics classes (815 boys and 697 girls) was used. In addition to investigating gender differences in learning environment perceptions, we also explored gender differences in student achievement and attitudes. 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 because it 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 gender 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 consisting 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 attitude and achievement, eight QTI scales and four MCI scales) was a 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 together.

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 behaviour and classroom climate more favourably than boys did, and this is consistent with previous research (Fraser, Giddings, & McRobbie, 1995; Lawrenz, 1987). The girls consistently rated more highly teacher behaviours that have positive connotations (Understanding and Helping/Friendly) and lower on interactional behaviours that have negative connotations (Uncertain, Dissatisfied 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 magnitudes of significant gender differences on QTI and MCI scales generally were small, measuring 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 | | |   |
|---------------------|------|------------------|---|------------------|---|------------------|---|
|                     | Mean | SD               |   | Mean | SD               |   | t     |   |
| Student Outcomes    |      |                  |   |      |                  |   |       |   |
| Attitude            | 26.25| 1.77             |   | 26.60| 1.85             |   | -1.63 |   |
| Achievement         | 5.97 | 1.44             |   | 5.57 | 1.49             |   | 3.66* |   |
| QT/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

Part 8: Conclusion and Discussion

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 is the modification and validation of two widely-applicable classroom climate instruments. A modified version of the Questionnaire on Teacher Interaction (QTI) was used to assess teacher-student interpersonal behaviour 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 primary mathematics classrooms, data were subjected to a series of correlational analyses (simple, multiple and canonical correlation) and multilevel (hierarchical linear model) analyses, using two levels of analysis (the student and the class). The results were fairly 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 an emphasis on more teacher Leadership, Helping/Friendly and Understanding behaviours and less Uncertain behaviour, 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. These findings inform educators about how to improve student achievement and attitudes by giving greater emphasis to learning environment aspects correlated positively to outcomes and less emphasis of dimensions negatively correlated with outcomes.

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 behaviour 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). Interpersonal teacher behaviour and classroom climate each made a sizeable unique contribution to the variance in student attitudes but not student achievement, thus suggesting the fruitfulness of including the QTI and MCI together in future studies of student attitudes (but not 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 set of 14 outcome and classroom environment scales. Although there were no differences in the attitude of boys and girls towards mathematics, boys showed superior mathematics achievement. Generally, the gender differences in perceptions of classroom environment were small in magnitude but consistent in direction for all the environment scales, with girls generally holding more favourable learning environment perceptions than boys.

Overall, the distinctive contribution which this study made to the field of learning environment research can be summarised as follows:

- Although much research on learning environments has been completed at the secondary school level, this study provides one of the most comprehensive of the relatively small number of studies undertaken at the primary school level.
- This study is one of a small handful that marks the beginning of the field of classroom environment research in Singapore.
- For the first time in any country, a primary version of the Questionnaire on Teacher Interaction (QTI) was developed, validated and used in research applications.
- The My Class Inventory (MCI) was adapted and cross-validated for use in Singapore.
- The study provided one of the first uses of multilevel analysis in learning environment research (and included a comparison of results from using well-established multiple regression techniques).
- By using two learning environment instruments within the same study (the QTI and MCI), it was possible to ascertain the unique and joint contributions of each instrument to student outcomes, therefore providing insights into the usefulness of including both instruments together in future research.
- The research included one of the few investigations of gender differences in students' learning environment perceptions.
Although the present pioneering study predominantly involved the use of quantitative methods, the qualitative methods used in the pilot study formed a most important part of the overall study. Moreover, now that the present initial study has used quantitative methods to validate widely-applicable instruments for future use, it is highly desirable to combine qualitative and quantitative methods in future research with these instruments as recommended by Fraser and Tobin (1991).

References


APPENDIX A

Questionnaire on Teacher Interaction (QTI)

Directions

This questionnaire is not a test. We want to know your opinion about how your teacher works with you.
We want you to answer honestly.
Read each sentence carefully.
Show your opinion about your teacher by circling:

1 if you think that your teacher behaves this way SELDOM
2 if you think that your teacher behaves this way SOMETIMES
3 if you think that your teacher behaves this way MOST OF THE TIME

Please answer all questions. If you want to change an answer, just cross it out and circle another answer.

Items are arranged in cyclic order so that the first, second, third, fourth, fifth, sixth, seventh and eighth item in each group of eight items assesses, respectively, Leadership, Helping/Friendly, Understanding, Student Responsibility/Freedom, Uncertain, Dissatisfied, Admonishing and Strict behaviour. Items are scored 1, 2 and 3, respectively, for the responses Seldom, Sometimes and Most of the Time. Omitted or invalid items are scored 2.
1. We all listen to this teacher
2. This teacher is friendly.
3. This teacher trusts us.
4. This teacher allows us to work on things that we like.
5. This teacher doesn't seem sure.
6. This teacher is unhappy.
7. This teacher gets angry quickly.
8. This teacher makes us work hard.
9. We learn a lot from this teacher.
10. This teacher likes to laugh.
11. This teacher knows when we do not understand.
12. We can decide some things in this teacher's class.
13. This teacher is not sure of himself/herself.
14. This teacher is bad-tempered.
15. This teacher looks down on us.
16. We have to be quiet in this teacher's class.
17. This teacher gets our attention.
18. This teacher's class is pleasant.
19. This teacher is willing to explain things again if we don't understand.
20. This teacher gives us a lot of free time in class.
21. This teacher is shy.
22. This teacher thinks that we can't do things well.
23. This teacher makes fun of us.
24. This teacher's tests are hard.
25. This teacher knows everything that goes on in this classroom.
26. We like this teacher.
27. This teacher takes notice of what we say.
28. This teacher allows us to choose who we work with.
29. This teacher is not sure what to do when we fool around.
30. This teacher thinks we cheat.
31. This teacher shouts at us.
32. This teacher is strict when marking our work.
33. This teacher explains things clearly.
34. This teacher helps us with our work.
35. This teacher knows how we feel.
36. This teacher allows us to fool around in class.
37. This teacher allows us to tell him/her what to do.
38. This teacher thinks that we know nothing.
39. It is easy to make this teacher angry.
40. We are afraid of this teacher.
41. This teacher is sure about what he/she wants to take place in the classroom.
42. This teacher cares about us.
43. This teacher listens to us.
44. This teacher allows us to choose what we want to work on.
45. This teacher acts as if he/she does not know what to do.
46. This teacher says that he/she will punish us.
47. This teacher has a bad temper.
48. This teacher is strict.
APPENDIX B
My Class Inventory (MCI)

Directions
This is not a test. The sentences are to find out what your class is like. We want you to answer honestly. Read each sentence carefully. Show what your class is like by circling:

1 if you think the practice SELDOM takes place
2 if you think the practice SOMETIMES takes place
3 if you think the practice MOST OF THE TIME takes place

Please answer all questions. If you want to change your answer, just cross it out and circle the new answer.

1. In my class everybody is my friend.
2. We race to see who can finish first.
3. Some pupils fight in my class.
4. The pupils are quiet in my class.
5. Some pupils in my class are not my friends.
6. Most children want their work to be better than their friend's work.
7. Some pupils in my class are unkind.
8. The class is noisy.
9. All the pupils are good friends.
10. Some pupils feel bad when they don't do as well as others.
11. Many pupils in my class like to fight.
12. All the pupils in my class hand in their work on time.
13. All the pupils in my class like one another.
14. Some pupils try to do their work better than the others.
15. Some pupils want to have their own way.
16. Some pupils spend more time talking about other things than about lessons.
17. Children in our class like each other as friends.
18. A few of the children in my class want to be first.
19. Children in our class fight a lot.
20. Some pupils do not complete their work in class.

Items are arranged in cyclic order so that the first, second, third and fourth item in each group of four items assesses, respectively, Cohesion, Competition, Friction and Task Orientation. Items with their item numbers underlined are scored 3, 2, and 1, respectively, for the responses Seldom, Sometimes and Most of the Time. All other items are scored in the reverse manner. Omitted or invalid responses are scored 3.