A Study of Computer-Assisted Learning Environments in Singapore

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Abstract

The present study filled some gaps in past learning environment research in that, first, it involved the development of a new instrument tailor-made specifically for use in computer-assisted learning (CAL) classrooms and, second, it provided one of the rare examples of an evaluation of computer-assisted learning based on its impact on the nature of a classroom learning environment as perceived by students. In addition, the research was conducted in the unique milieu of the Singapore school system, and it investigated associations between students’ outcomes and the classroom environment in computer-assisted learning settings.

Descriptors: Computer-assisted learning, learning environment, geographic education

Background

In Singapore, educational applications of computers were only introduced fairly extensively into the schools in 1980. The focus initially was on teaching computer science as a subject at the pre-university level and low-level computer literacy courses at the secondary school level. There was no extensive computer education programme at the primary level (Wong, Lim and Low, 1989). Computer-assisted learning (CAL) was only introduced to the schools in 1986. Currently, schools use CAL in Science, Mathematics and English for remediation and enrichment. No Singaporean schools develop their own CAL courseware (Wong, Lim and Low, 1989).

However, in Singapore, there is a dearth of research on the effects of CAL. To date, only three research studies have been conducted (Ong and Lee-Leck, 1986; Low, 1988; Woo-Tan, 1989). On the whole, positive effects of CAL have been reported. However, because the samples in these studies were small and non-random, and because of the short duration of the experimental treatment and the narrow scope of the content selected, their findings should be interpreted with caution. Furthermore, the sample selected in one of the studies was from one of the best schools in the country, thus limiting the generalisability of the results obtained. Thus, research data on the use of CAL in Singapore is sparse, of questionable validity and of low generalisability. Because of the lack of dependable research information, and in view of the potential that research conducted in the unique educational context of Singapore has for our understanding of computer-assisted learning environments, the present study was conceptualised and conducted.
Learning Environment Research

It is now a quarter of a century since the Learning Environment Inventory was used as part of the research and evaluation activities of Harvard Project Physics (Welch and Walberg, 1972). Around the same time, Moos began developing social climate scales for a wide variety of human environments, including the Classroom Environment Scale for use in school settings (Moos and Trickett, 1987). Since that time, new classroom environment instruments have been developed to assess specific settings, such as the Individualised Classroom Environment Questionnaire for open or individualised classrooms (Fraser, 1990) and the Science Laboratory Environment Inventory for science laboratory classes (Fraser, McRobbie and Giddings, 1993). The present study extended past research in another new direction in that it involved the development, validation and use of a new instrument for assessing the unique setting of the computer-assisted learning classroom.

The strongest tradition in past classroom environment research has involved investigation of associations between student outcomes and their perceptions of classroom environment (Fraser and Fisher, 1982). A meta-analysis of 734 correlations from 82 classes in 8 subject areas containing 17,805 students in 4 nations revealed that classroom environment perceptions accounted for appreciable amounts of variance in cognitive and affective outcomes, often beyond that attributable to background student characteristics (Haertel, Walberg, and Haertel, 1981). The practical implication from this research is that student outcomes might be improved by creating classroom environments found empirically to be conducive to learning. In the present study, one of the major purposes was to explore associations between students’ achievement and attitudes and their perceptions of their computer-assisted classroom learning environments.

Researchers in various countries have used student perceptions of the classroom environment as criterion variables in studies aimed at identifying how perceptions vary with such factors as class size (Anderson and Walberg, 1972), grade level (Welch, 1979), student gender (Lawrenz, 1987), subject matter (Tamir and Cardin, 1993) and type of school (Trickett, 1978). Also, students’ classroom environment perceptions have been found to differ systematically from those of their teachers (Fisher and Fraser, 1983) and to provide a tangible basis for guiding improvements in classrooms (Fraser and Fisher, 1986).

One promising but largely neglected use of student perceptions is as a source of process criteria in evaluating educational innovations (Fraser, 1981). For example, an evaluation of Harvard Project Physics showed that students’ perceptions of the classroom environment differentiated revealingly between curricula, even when various outcome measures showed negligible differences (Welch and Walberg, 1972). The research reported in this study is distinctive in that it provides one of the first evaluations of CAL which investigated the psychosocial environment of CAL classrooms.

Although there has been a revolution in recent years in terms of both the scope and variety of the roles which computer-assisted learning has played within education, the field of classroom learning environment (Fraser, 1986, 1993; Fraser and Walberg, 1991) has lagged behind in two major ways. First, hitherto there has existed no learning environment instrument which has been tailor-made specifically for use in classrooms using computer-assisted learning. Second, innovations in computer-assisted learning have rarely been evaluated in terms of their impact on the nature of the classroom learning environment as perceived by students (Ellett, 1986; MacGregor, 1986). The present study fills some of the gaps by reporting the evaluation of an innovation in computer-assisted learning in terms of its impact on classroom environment, in addition to reporting on its impact on student achievement and attitudes, and associations between student outcomes and classroom environment.
Purposes of Study

The main purposes of the study were:

(1) to develop and validate a new instrument for assessing the unique learning environment of computer-assisted learning classrooms;

(2) to evaluate an innovation in computer-assisted learning, involving the use of micro-PROLOG for teaching the topic of decision making in geography in Singapore schools, in terms of impact upon:
   • student achievement;
   • student attitudes;
   • the classroom environment.

(3) to investigate associations between students’ cognitive and affective outcomes and the nature of the learning environment in computer-assisted classroom settings.

Design

The Innovative Teaching Approach

The innovation in computer-assisted learning which formed the focus of this study was distinctive in that it made use of micro-PROLOG, the microcomputer version of PROLOG, a high-level fifth-generation declarative language, which was developed for artificial intelligence research and which has been found to be robust, compact and accessible to students in classroom applications (Chalk, 1987). This CAL courseware covered the topic of decision-making in geography and was designed specifically for a six-week segment in the Singapore school geography syllabus. In order to enhance the validity of conclusions from the evaluative study, a control group, which studied the same topic via the direct expository teaching methods common in Singapore, was also included in the study.

The CAL approach consisted of a sequence of instructions consisting of learning activities for the concept of decision-making, followed by a prescribed set of exercises. During the CAL lessons, students were presented with the necessary information. Also students were guided with instructions on the computer screens, were provided with practice exercises and had their learning assessed. Feedback was provided contingent upon correct and incorrect responding.

Sample

The study involved 12 teachers, each in a different randomly selected school. In order to reduce the “teacher effect”, each teacher taught one experimental and one control class. All schools were coeducational in order to allow an unconfounded test of whether CAL was differentially effective for boys and girls. The total number of students in these 24 classes was 671 (348 in the experimental group and 323 in the control group). Approximately equal numbers of males and females made up the sample. Students were 8th graders from the lower end of the ability range in Singapore (referred to as “Secondary 2 Normal” students).

Development of Instruments

Geography Achievement Test (GAT) and Semantic Differential Inventory (SDI)

The instruments used to measure achievement in and attitude towards geography were developed and validated during the study. The Geography Achievement Test (GAT) is a 30-item multiple-choice test which assesses the concept of decision-making in geography. The Semantic Differential Inventory (SDI) is a 20-item semantic differential instrument which measures students’ attitudes towards learning geography. The alpha reliability coefficient for the whole sample was found to be 0.95 for the 30-item GAT and 0.94 for the 20-item SDI.

The Geography Classroom Environment Inventory (GCEI)

Description of GCEI

The final version of a new instrument developed for this study, called the Geography Classroom
Environment Inventory (GCEI), has four Likert-type scales. The response alternatives for each item are Almost Never, Seldom, Sometimes, Often and Very Often. The initial GCEI instrument contained the eight scales of Teacher Concern, Participation, Gender Equity, Investigation, Innovation, Differentiation, Organisation and Resource Adequacy, but four scales (namely, Teacher Concern, Participation, Differentiation, and Organisation) were omitted after item and factor analyses. Each scale was selected because of its relevance to the unique environment of CAL classes; a justification for scale selection is provided in a later section.

Eight items are contained in the final version of each scale. Typical items contained in the GCEI are “The teacher pays more attention to boys’ questions than to girls’ questions” (Gender Equity), “Students carry out investigations to answer questions coming from class discussions” (Investigation), “New and different ways of teaching are used in this class” (Innovation), and “There are enough computer programs available for our lessons” (Resource Adequacy). The scoring direction is reversed for almost half of the 32 items in the GCEI.

The initial development of the GCEI took cognisance of Moos’s three general dimensions as they apply to all human environments (Moos, 1974). These three general dimensions are Relationship Dimensions (the nature and intensity of personal relationships within the environment), Personal Development Dimensions (the basic directions along which personal growth and self-enhancement tend to occur) and System Maintenance and System Change Dimensions (the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change). Table 1 shows that the four scales in the final version of the GCEI provide reasonable coverage of the three different basic types of dimensions proposed by Moos.

**Development of GCEI**

The development of the GCEI was guided by the following four criteria:

1. **Consistency with the Literature on Computer-Assisted Learning.** A review of the literature was undertaken to identify scales that are considered important in the unique environment of computer-assisted learning (Heywood and Norman, 1988; Ely, 1990; Tolman and Allred, 1991). This is discussed in greater detail below.

2. **Coverage of Moos’s General Classification.** As discussed earlier, scales were chosen that provided coverage of the three general types of dimensions identified by Moos (1974) for conceptualising all human

<table>
<thead>
<tr>
<th>Scale Name</th>
<th>Description</th>
<th>Moos’s Description</th>
</tr>
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<tbody>
<tr>
<td>Gender Equity</td>
<td>Extent to which boys and girls are treated equally by the teacher.</td>
<td>Relationship</td>
</tr>
<tr>
<td>Investigation</td>
<td>Extent to which the skills and processes of inquiry are used in problem solving and investigation.</td>
<td>Personal Development</td>
</tr>
<tr>
<td>Innovation</td>
<td>Extent to which the teacher plans new and varying activities and techniques and encourages students to think creatively.</td>
<td>System Maintenance</td>
</tr>
<tr>
<td>Resource Adequacy</td>
<td>Extent to which the computer hardware and software are adequate.</td>
<td>System Maintenance</td>
</tr>
</tbody>
</table>
environments. Because Moos (1974) claims that, at minimum, Relationship Dimensions, Personal Development Dimensions and System Maintenance and System Change Dimensions must be included to provide an adequate and reasonably complete picture of any environment, dimensions for the initial GCEI instrument were chosen to include scales in each of Moos's three general categories.

3. Salience to Classroom Environment Researchers, Teachers and Students. By soliciting comments and feedback from geography teachers and students at the "Secondary Two" level in Singapore on draft versions of sets of items, an attempt was made to ensure that the initial GCEI’s scales and individual items were considered salient by teachers and students. Additionally, the reactions of several educational researchers with extensive experience in classroom environment research and questionnaire development were sought concerning the adequacy, suitability and relevance of the items that made up the scales. This led to the fine-tuning and refinement of the items and scales to form a modified version of the GCEI instrument.

4. Salience to Computer Education Experts. Several computer education experts vetted the items and scales and agreed that the constructs were relevant.

Justification for Choice of Dimensions
The Gender Equity scale was created and included in the GCEI for this study because classroom environment instruments in past research have not included this scale when they were used as sources of predictor and criterion variables (Fraser, McRobbie, and Giddings, 1993). Although Lawrenz (1987) investigated gender effects for students’ perception of their science classroom environment, she used the shorter versions of the Learning Environment Inventory developed by Fisher and Fraser (1983) and validated by Fraser and Fisher (1986). But no gender equity scale was included in these two instruments. Although Lawrenz’s (1987) study does not suggest a cause and effect relationship, it was found that the perceived classroom environment was related to both teacher and student gender. Despite the fact that Fraser, McRobbie and Giddings' (1993) study had, as one of its major aims, the investigation of gender differences in perceptions of science laboratory classrooms using the Science Laboratory Environment Inventory (SLEI), the SLEI did not include gender equity as one of its scales. Nevertheless, their findings suggest that females generally perceived the science laboratory classroom environment more favourably than did males. A classroom environment instrument which includes a gender equity scale is likely to be able to detect gender effects even more sensitively.

Gender Equity was also included in the instrument because a decade of research on this topic in the CAL environment has shown that the use of computers maintained and exaggerated inequities, that equity issues are complex (Sutton, 1991), and that there are gender differences in achievement and attitudes towards computer usage (Hattie and Fitzgerald, 1987; Sutton, 1991).

Previously-developed classroom environment instruments have included innovation, resource adequacy (or “material environment”) and investigation as dimensions. Innovation was included as one of the dimensions of GCEI because the use of microcomputers as an effective educational innovation has been discussed in the computer education literature. The literature suggests that the microcomputer has been accepted as an educational innovation (Heywood and Norman, 1988), that the government plays an active role in promoting computer use in the educational system, and that the use of microcomputers as an educational innovation can affect outcomes (Boyd, 1990).

Resource Adequacy (or “Material Environment”) is one of the scales that has been included in past classroom environment research (Fraser, McRobbie and Giddings, 1993). In the computer education literature, resource adequacy refers to the use of computer software (sometimes called courseware) or hardware for
teaching and learning. The need to create software that the teacher can use as a tool in teaching has been discussed widely in the literature (Plomp and Pelgrum, 1991), as has the type and quality of educational software (Gonce-Winder and Walbesser, 1987; OECD-CERI, 1989). Also, some researchers are concerned about hardware acquisition and utilisation (Boyd, 1990; Plomp and Pelgrum, 1991).

Although there has been a strong tradition in CAL research at all school levels to investigate the effectiveness of the usage of CAL in a specific cognate area (Roblyer, Castine and King, 1988; Kulik and Kulik, 1991), past CAL research has seldom examined the potential of computer usage in facilitating and promoting student investigation in the classroom. Therefore investigation was another dimension that was incorporated into the GCEI instrument.

Refinement and Validation of GCEI

A preliminary 80-item version of the GCEI, with 10 items in each of 8 scales, was field tested and modified to form a final 32-item version (with 8 items in each of 4 scales). The instrument refinement process involved the three stages described below: interviews with students, item analysis of students’ responses, and factor analyses of students’ responses.

Preliminary Field Testing and Student Interviews

In order to improve the initial form of the GCEI prior to its use in the main study, it was field tested with two complete classes of lower ability students (38 boys and 32 girls) in Secondary Two Normal classes. The two classes were assigned randomly as experimental and control groups, respectively. The experimental class used the CAL module, while the control class followed the lessons via the normal expository mode. At the end of the treatment, students responded to the GCEI and, immediately after administration, students were interviewed and their evaluations were sought concerning the GCEI in terms of the appropriateness and level of the language used, syntax and rubric. In addition to students’ evaluations, the comments of the class teachers and Heads of Department were also obtained.

This subjective approach led to the identification of several sources of ambiguity and misinterpretation. Subsequently, some minor but important changes were made to selected GCEI items to overcome those problems prior to its use in the main study as described below.

Item Analysis

Further modifications to the GCEI instrument were based on item analyses of the data collected in the main study from the sample of 24 classes of Secondary 2 Normal students (N = 671). These items analyses were carried out to identify items whose removal would enhance each scale’s internal consistency and discriminant validity. In particular, internal consistency was enhanced by removing any item with a low item-remainder correlation (i.e., correlation between an item score and the total for the remaining items in that scale), and discriminant validity was enhanced by removing any item whose correlation with its a priori assigned scale was lower than its correlation with any other scale in the GCEI. The application of item analysis procedures to the initial version of GCEI led to the deletion of 11 of the 80 items in order to enhance each scale’s internal consistency and discriminant validity.

Factor Analyses

Next, the same students’ responses (N = 671) to the 69 items in the initial version of the GCEI which survived the item analysis procedures were factor analysed using principal components analysis with varimax rotation to generate orthogonal factors. Several factor analyses using the individual as the unit of analysis were obtained and examined. Four factors, with eigenvalue of 1.0 and above, were found to explain 55.2% of the total variance in GCEI scores. Items with factor loadings greater than or equal to the conventionally accepted value of 0.30 were retained in the analysis. These
factor analyses led to the deletion of 4 of the original scales, namely, Teacher Concern, Participation, Differentiation and Organisation. The factor analyses also led to the deletion of a small number of individual items in the remaining scales. With the deletion of some scales and individual items, a final modified 32-item 4-factor version of the GCEI was produced.

Each of the 32 items in the final version of the GCEI was allocated to the same scale as the original version. Also every item had a factor loading greater than 0.30 with its a priori scale and less than 0.30 with each of the other 3 scales.

Appendix A contains a copy of the final version of the GCEI. The first, second, third and fourth item in each block in Appendix A assesses, respectively, Gender Equity, Investigation, Innovation and Resource Adequacy. The number circled represents the score allocated except for items with R in the for Teacher’s Use column; these items are scored in the reverse manner. Items which have been omitted or whose answers are invalid are scored as 3.

**Validation Statistics for Modified Version of GCEI**

Table 2 shows the statistics obtained with the 348 students in the experimental (computer) group for each of the GCEI scale’s internal consistency (alpha reliability) and discriminant validity (correlations between scales). These indices were calculated using the individual as the unit of statistical analysis. Data in Table 2 generally show that, for this sample, the GCEI scales displayed adequate internal consistency reliability (with alpha coefficients ranging from 0.52 to 0.68) and discriminant validity (with mean correlations ranging from 0.01 to 0.45). Validation data were fairly similar for the control group.

Table 2 also provides information about each scale’s ability to differentiate between the perceptions of students in different classrooms. These results were obtained by performing a one-way ANOVA for each scale, with class membership as the main effect and using the individual as the unit of analysis. Results of these analyses reported in Table 2 indicate that each of the four scales differentiated significantly (p<0.01) between the perceptions of students in different classrooms. The $\eta^2$ statistic, which represents the proportion of variance in environment scores accounted for by class membership, ranged from 0.38 to 0.64 for the various scales. The results for the control group were fairly similar.

**Impact of CAL on Achievement, Attitudes and Classroom Environment**

**Achievement and Attitudes**

A comprehensive synthesis of 134 past meta-analyses of 7,827 individual studies of factors affecting student achievement by Fraser,

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of Items</th>
<th>Alpha Reliability</th>
<th>Scale Intercorrelations</th>
<th>ANOVA Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>GE</td>
<td>IV</td>
</tr>
<tr>
<td>Gender Equity (GE)</td>
<td>8</td>
<td>0.67</td>
<td>0.01</td>
<td>0.22</td>
</tr>
<tr>
<td>Investigation (IV)</td>
<td>8</td>
<td>0.65</td>
<td>0.45</td>
<td>0.10</td>
</tr>
<tr>
<td>Innovation (IN)</td>
<td>8</td>
<td>0.52</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Resource Adequacy (RA)</td>
<td>8</td>
<td>0.68</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** $p<0.01$
Walberg, Welch and Hattie (1987) has shown that the average effect size in past studies in education is only 0.4 standard deviations. For computer-based instructional programs, in particular, a review by Roblyer, Castine and King (1988) also revealed an average effect size of 0.4 standard deviations, while Kulik and Kulik’s (1991) meta-analysis of computer-based learning effectiveness revealed a value of 0.3 standard deviations.

In contrast, the present evaluation of the use of PROLOG-based computer-assisted learning revealed a massive effect size of 3.5 standard deviations (of difference between the experimental CAL group and the control group) for the achievement outcome and an effect size of 1.4 standard deviations for the attitude measure. These differences favoured the CAL group.

**Classroom Environment**

To investigate differences in students’ perceptions of their actual classroom environment between the experimental (computer) and control (non-computer) group, ANCOVA procedures were computed separately for each of the four scales in the GCEI. A summary of the results for significance of differences between the perceptions of the computer and non-computer groups are reported in Table 3. The effect sizes (i.e., the number of standard deviations of difference between the experimental CAL group and the control group) for each of the 4 GCEI scales are also reported here.

Table 3 shows the ANCOVA results when three different measures (namely, students’ national primary school leaving examination scores, examination marks obtained in the previous semester, and their pretest scores) were used as covariates. Significant differences (p<0.01) emerged in the students’ perceptions between the computer and non-computer group for all of the four GCEI scales, namely, Gender Equity, Investigation, Innovation and Resource Adequacy. Table 3 also reveals that the use of PROLOG-based computer-assisted learning was associated with an effect size of 1.0 standard deviations for Gender Equity, 1.9 standard deviations for Investigation, 1.7 standard deviations for Innovation and 1.5 standard deviations for Resource Adequacy. These differences favoured the CAL group in every case. Relative to control classes, the CAL classes were perceived to have greater gender equity, investigation, innovation and resource adequacy. The present study’s findings in the context of computer-assisted learning are consistent with past studies of non-CAL classroom environments (Fraser, 1981, 1986) in which learning environment measures have proved useful in curriculum evaluation.

**Associations Between Student Outcomes and Classroom Environment**

In past classroom environment research, it has been common to investigate associations between student outcomes and the nature of the classroom environment (Fraser and Fisher, 1982; Fraser, 1986). One of the purposes of the present study was to investigate outcome-environment associations in a CAL environment.

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of Items</th>
<th>F</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender Equity</td>
<td>8</td>
<td>219.66**</td>
<td>1.0</td>
</tr>
<tr>
<td>Investigation</td>
<td>8</td>
<td>809.14**</td>
<td>1.9</td>
</tr>
<tr>
<td>Innovation</td>
<td>8</td>
<td>703.63**</td>
<td>1.7</td>
</tr>
<tr>
<td>Resource Adequacy</td>
<td>8</td>
<td>504.28**</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**p<0.01
This involved using data collected for the sample of 671 geography students to relate their scores on the geography achievement and attitude instruments to scores on the four classroom environment scales.

Table 4 reports the results obtained when outcome-environment relationships were investigated for the two previously described outcomes of achievement (as measured by a Geography Achievement Test) and attitudes (measured by a Semantic Differential questionnaire). The four different methods of data analysis (including the use of the individual as the unit of analysis) involved simple, semipartial simple, multiple and semipartial multiple correlation techniques.

The first type of analysis involved simple correlations ($r$) between an outcome posttest measure and each of the four environment scales, whereas the second type of analysis involved the semipartial simple correlation between an outcome and each environment scale with control for corresponding pretest and general ability (assessed by the national primary school leaving examination scores and the previous semester’s examination scores).

Past research practice has tended to involve the performance of a conservative test of outcome-environment relationships by statistically controlling certain student characteristics, especially corresponding pretest and general ability. That is, learning environment scales have been considered useful predictors of student learning outcomes only if they accounted for different variance from that attributable to well-established predictors like pretest and general ability (Walberg and Haertel, 1980). However, Fraser and Fisher (1982) and Fraser (1986) argue that, while conservative analyses in which student characteristics are controlled have the merit that that they do not overestimate the variance component attributable to environment, they might well underestimate the importance of the environment component because any variance shared by environment and student characteristics is removed. Hence, the simple correlation analysis was computed twice, once without adjustment for corresponding pretest and general ability and once with adjustment for pretest and general ability.

The results in Table 4 show that outcome-environment associations were all significant ($p<0.01$) for both the simple and semipartial simple correlation analyses for both the achievement and attitude outcome. All significant outcome-environment relationships were positive. The interpretation of these significant correlations was that greater levels of these environment scales were associated with higher achievement in geography and more positive attitudes.

The third type of analysis reported in Table 4 consists of a multiple correlation analysis ($R$) involving the whole set of four classroom environment scales and performed for each outcome. The multiple correlation analysis provides a more parsimonious picture of the joint influence of correlated environment scales on an outcome and reduces the Type I error rate associated with the simple correlational analyses. The multiple correlation was found to be 0.76 ($p<0.01$) for the achievement outcome and 0.66 ($p<0.01$) for the attitude outcome. An examination of the beta weights ($\beta$) (i.e., the standardised regression weights) in Table 4 shows that all the environment scales were related significantly and positively to both the achievement outcome and the attitude outcome when the other three environment scales were held constant.

The last line in Table 4 reports the results of the fourth type of analyses, namely, a semipartial multiple correlation analysis between an outcome and the set of environment scales with pretest and general ability controlled. Significant semipartial multiple correlations of 0.55 ($p<0.01$) for achievement and 0.40 ($p<0.01$) for attitude were found. The square of the semipartial multiple correlation ($sr^2$) is equal to the proportion of variance in an outcome measure uniquely attributable to the set of GCEI scales beyond that accounted for by pretest and general ability scores (Cohen and Cohen, 1983). It can be concluded that the set of 4 GCEI scales as a whole accounted for a significant amount of variance in the achievement outcome measure.

The beta weights in Table 4 suggest the
Table 4: Simple ($r$), Semipartial Simple ($sr$), Multiple ($R$) and Semipartial Multiple ($sR$) Correlations Between Classroom Environment Scales and Two Student Outcomes (Achievement and Attitude)

<table>
<thead>
<tr>
<th>Classroom Environment Scale</th>
<th>Simple Correlation ($r$)</th>
<th>Semipartial Simple Correlation ($sr$)</th>
<th>Regression Weight Without Control for Pretest &amp; General Ability ($\beta$)</th>
<th>Regression Weight With Control for Pretest &amp; General Ability ($\beta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Achievement</td>
<td>Attitude</td>
<td>Achievement</td>
<td>Attitude</td>
</tr>
<tr>
<td>Gender Equity</td>
<td>0.46**</td>
<td>0.44**</td>
<td>0.48**</td>
<td>0.44**</td>
</tr>
<tr>
<td>Investigation</td>
<td>0.64**</td>
<td>0.52**</td>
<td>0.68**</td>
<td>0.56**</td>
</tr>
<tr>
<td>Innovation</td>
<td>0.64**</td>
<td>0.53**</td>
<td>0.68**</td>
<td>0.57**</td>
</tr>
<tr>
<td>Resource Adequacy</td>
<td>0.60**</td>
<td>0.57**</td>
<td>0.63**</td>
<td>0.58**</td>
</tr>
<tr>
<td>Multiple Correlation $R$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semipartial Multiple</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correlation $sR$</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* $p<0.05$

** $p<0.01$
following interpretations for the significant outcome-environment relationships from both the multiple and semipartial multiple correlation analyses: both geography achievement and attitude scores were higher in classes perceived to practise more gender equity, to give more emphasis to investigation, to be more innovative and to have more adequate resources.

On the whole, the results of the different types of analyses reported in Table 4 establish sizeable and statistically significant associations between both achievement and attitude outcome and students’ perceptions of their CAL classroom environment. This relationship found between student outcome and classroom environment is consistent with past research reported by Fraser (1986, 1991, 1993) and Fraser, McRobbie and Giddings (1993).

Discussion

The study's focus on the learning environment associated with the use of computer-assisted learning in school geography education in Singapore is distinctive because, first, the use of CAL in geography education has been sparse relative to other disciplines, second, research on CAL in geography education in Singapore hitherto has been non-existent and third, only a very small amount of classroom environment research has previously been undertaken in Singapore. In addition, the present research extended learning environment work in a new direction by developing and using a new instrument for assessing student perceptions of CAL classroom environments.

This study shows that appropriately-designed PROLOG-based CAL can be an effective instructional method in the classroom milieu. It also shows that the educational application of micro-PROLOG as a learning tool in social science classrooms can be efficacious. While a myriad of studies have examined the effects of CAL, the number of studies examining the effect of PROLOG-based CAL is meagre at best. Hopefully, this study will serve as a catalyst for further research into the use of PROLOG in the classroom.

No systematic attempts have previously been made to examine the effects of CAL on learning environment characteristics. Little has been studied or is known about the impact of microcomputers on learning climates in education (Ellett, 1986). This study responds to the plea by Ellett (1986) and Lancy (1987) to fill the lacunae represented by the study of computers and their impact on students. This study is significant because, in contrast to previous research, it uses PROLOG-based courseware developed by the investigators in assessing computer learning environments in schools.

One of the study’s major contributions was that a new classroom environment instrument was developed and validated specifically for the unique setting of computer-assisted learning. The scales in this instrument were found to display adequate factorial validity, internal consistency reliability and discriminant validity. Also, each scale differentiated significantly between the perceptions of students in different classrooms. It is likely that other researchers may find this new instrument useful in future studies of CAL classroom environments.

Another major finding was that, in contrast to past research, the use of CAL in this study led to a massive impact in terms of achievement (effect size of 3.5 standard deviations), attitude (1.4 standard deviations) and classroom environment (ranging from 1.0 to 1.9 standard deviations). The large effect sizes arising from this study could be attributed to the peculiar situation inherent in the Singapore education system. That is, the highly meritocratic, technologically-biased, centrally-controlled and achievement-oriented system propels students to perform well. The large effect sizes could also be attributable to the PROLOG-based CAL courseware developed for this study. This CAL courseware took cognisance of the curriculum objectives of the schools, the prerequisites of following the exact curriculum topics, and the integration of the courseware with the syllabus requirements of the schools. The large effect sizes seem to suggest that appropriate computer-based teaching is effective with low aptitude students (ie the Normal students). This finding is
consistent with the meta-analysis of CAL effectiveness reviewed by Kulik and Kulik (1991). But there is a need for replication and further related research because of the uniqueness of the Singapore milieu.

An investigation of associations between student outcomes and the nature of the classroom environment replicated past research in that both achievement and attitudes were enhanced in classes providing a more positive environment in terms of all of the dimensions assessed (namely, gender equity, innovation, investigation and resource adequacy).

There is considerable scope to make use of the new instrument for computer-assisted learning environments in replicating the present evaluation of innovations in CAL and the present investigation of the effects of CAL classroom environments on student outcomes. In addition, it is hoped that researchers will make use of the new questionnaire specifically in CAL settings in pursuing some of the other lines of classroom environment research reviewed by Fraser (1993). These include the use of classroom environment research in school psychology (Burden and Fraser, in press), person-environment fit investigations of whether students achieve better in their preferred classroom environment (Fraser and Fisher, 1983), practical attempts to improve the classroom setting (Fraser and Fisher 1986), studies of links between classroom-level and school-level climate (Fisher and Fraser, in press) and research which combines qualitative and quantitative methods in the study of learning environments (Fraser and Tobin, 1991).

REFERENCES


APPENDIX A

MODIFIED GEOGRAPHY CLASSROOM ENVIRONMENT INVENTORY (GCEI)
ACTUAL FORM

DIRECTIONS

This questionnaire contains statements about practices which take place in this classroom: You will be asked *how often* each practice takes place.

There is no “right” or “wrong” answers. Your opinion is what is wanted.

Please do not write on this questionnaire. All answers should be given on the separate Answer Sheet.

Think about how well each statement describes what the actual classroom is like. Draw a circle around:

1. If the practice actually takes place ALMOST NEVER
2. If the practice actually takes place SELDOM
3. If the practice actually takes place SOMETIMES
4. If the practice actually takes place OFTEN
5. If the practice actually takes place VERY OFTEN

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.
<table>
<thead>
<tr>
<th></th>
<th>The teacher pays more attention to boy’s questions than to girls’ questions.</th>
<th>1 2 3 4 5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Students find out the answers to questions from textbooks rather than from investigations.</td>
<td>1 2 3 4 5</td>
<td></td>
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<tr>
<td></td>
<td>New ideas are tried out in this class.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>This classroom is an attractive place in which to work.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Girls get to use the equipment as much as boys.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Students carry out investigations to test ideas.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>What students do in class is the same on each day.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>The computer are in good working condition.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Girls get less individual help from the teacher than do boys.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Students find out the answers to questions and problems from the teacher rather than from investigations.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>New and different ways of teaching are used in this class.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>The computers are suitable for operating the programs.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Boys have more say in this class than girls.</td>
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<td></td>
<td>Students are asked to think about information coming from investigations.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>The teacher likes students to try unusual projects.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>There are not enough computers for students to use.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>Girls and boys are treated the same in this class.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Students carry out investigations to answer questions coming from class discussions.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>The teacher thinks up new and interesting activities for students to do.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>The computer programs available enable students to make good use of the computer.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>The teacher encourages boys more than girls in this class.</td>
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<tr>
<td></td>
<td>Students depend on the teacher to carry out investigations.</td>
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<td></td>
<td>Students do the same type of activities every day.</td>
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<td></td>
<td>There are enough computer programs available for our lessons.</td>
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<td></td>
<td>Boys get more opportunity to use the equipment in this class.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Students carry out investigations to answer questions which puzzle them.</td>
<td>1 2 3 4 5</td>
<td></td>
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<tr>
<td></td>
<td>Students are given the same kind of homework each time.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>The computer programs run without any problems.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>The teacher expects the same standards of work from boys and girls.</td>
<td>1 2 3 4 5</td>
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<tr>
<td></td>
<td>Investigations are used to answer the teacher’s questions.</td>
<td>1 2 3 4 5</td>
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<td></td>
<td>In this class, students are allowed to make up their own projects.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The computer programs are hard to use.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

For Teacher’s Use Only: GE _______ Iv _______ In _______ RA _______