Psychosocial Environment of Science Laboratory Classrooms in Canadian Schools and Universities

Barry J. Fraser
curtin university of technology
Alan K. Griffiths
memorial university of newfoundland

The Science Laboratory Environment Inventory assesses students' or teachers' perceptions of five dimensions of actual or preferred classroom environment, namely, Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environment. The instrument was field-tested in Canada, Australia, the United States, England, Israel, and Nigeria, both in secondary and in post-secondary institutions. Various analyses attested to each scale's internal consistency, reliability, discriminant validity, factorial validity, predictive validity, and ability to differentiate between the perceptions of students in different classes. The instrument is equally valid for use in its actual and preferred versions, for senior secondary school and university laboratory classes, for the individual or the class mean as the unit of analysis, and for each of the six countries.

Le Science Laboratory Environment Inventory évalue les perceptions des étudiants ou des enseignants ayant trait à cinq facettes de la salle de cours, à savoir la cohésion des étudiants, l'ouverture, l'intégration, la clarté du règlement et l'environnement physique. L'instrument a été utilisé au secondaire et au post-secondaire au Canada, en Australie, aux États-Unis, en Angleterre, en Israël et au Nigeria. Diverses analyses attestent la cohérence interne, la fidélité, la validité discriminante, la validité factorielle et la validité prédictive de chaque échelle comme son pouvoir de différencier les perceptions des étudiants dans diverses classes. La validité de l'instrument a également été établie dans ses versions présente et préférée, pour une utilisation dans les dernières années du secondaire et les cours de laboratoire à l'université, pour la moyenne par individu ou par classe comme unité d'analyse et pour chacun de ses six pays.

This paper describes the development of a new instrument for assessing student perceptions of psychosocial environment in science laboratory classrooms, and reports comprehensive validation information for large samples of senior high school and university students from Canada and five other countries. The work is distinctive because it extends classroom environment research in non-laboratory settings to science laboratory classes, and provides one of the few classroom environment studies conducted in Canada during the last decade.

BACKGROUND

Laboratory teaching is one of the hallmarks of education in the sciences (Hegarty, 1987), but writers are questioning whether the great expense of maintaining and staffing laboratories is really justified (Hofstein & Lunetta, 1982; Walberg, 1991), and whether many of the aims of laboratory teaching could be pursued more effectively and at less cost in non-laboratory settings. However, we know little about the effects of laboratory instruction on student learning and attitudes. In reviewing 16 recent studies, Gallagher (1987) concluded that "Laboratory work is an accepted part of science instruction. Given its important place in the education of youth, it is surprising that we know so little about its functioning and effects" (p. 351). New research will illuminate students' views of laboratory settings and show the impact of laboratory classes on student outcomes.

Layton (1989) claims many teachers lack understanding of scientific inquiry or the skill to teach it. Although Tobin's (1986) ethnographic study of 15 teachers showed that both teachers and students value laboratory work, he also found most laboratory activities are insufficiently well implemented to facilitate genuine inquiry. At the university level, a content analysis of 500 laboratory exercises revealed that none allowed students to recognize problems, design experiments, or select methods and materials (Hegarty, 1987).

The previous two decades have witnessed considerable international interest in the conceptualization, measurement, and investigation of perceptions of psychosocial characteristics of learning environment in elementary, secondary, and higher education classrooms (Fraser, 1986, 1989, in press; Fraser & Walberg, 1991). Most recent classroom environment instruments have distinct versions measuring student perceptions of *actual* and *preferred* classroom environment. The preferred forms include goals and value orientations and preferred classroom environment. In the present study, parallel actual and preferred versions were developed and field-tested in six countries.

Classroom environment instruments have served as sources of predictor and criterion variables in international studies in elementary and secondary schools. Student perceptions of actual classroom environment are consistently related to student cognitive and affective outcomes (see Haertel, Walberg, & Haertel, 1981). For example, Fraser and Fisher's (1982) study involving 116 Australian science classes established sizeable associations between several inquiry skills and science-related attitudes and classroom environment dimensions measured by the Classroom Environment Scale and the Individualized Classroom Environment Questionnaire. Furthermore, research on person-environment fit has shown that students achieve better in classroom environments they prefer (Fraser & Fisher, 1983a).

Studies reviewed by Fraser (1986) and involving the actual form of scales as criterion variables have revealed that classroom psychosocial climate varies among different types of schools and between coeducational and single-sex schools. Both researchers and teachers have usefully employed classroom climate dimensions as criteria of effectiveness in curriculum evaluation because they differentiate revealingly between alternative curricula when student outcome measures show little sensitivity (Fraser, 1981). Research in several countries (Fraser, 1986) compared students' and teachers' perceptions and found that, first, both students and teachers prefer a more positive classroom environment than they perceive as being actually present and, second, teachers perceive the classroom environment more positively than do 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 to identify and discuss actual-preferred discrepancies, followed by a systematic attempt to improve classrooms (Fraser & Fisher, 1986).

Some of the pioneering classroom environment work, especially the development of the widely-used *Learning Environment Inventory*, was carried out in Canada. In particular, Anderson's (1970) research involving 1,600 grade 10 and 11 students in Montreal established that student perceptions of classroom environment account for significant amounts of learning outcome variance even when student background characteristics are accounted for. This finding was replicated later by O'Reilly (1975) with a sample of 48 grade 9 and 12 mathematics classes in Ontario. However, with a few notable exceptions (for example, Randhawa, 1991), Canadian researchers have conducted very little research on learning environments which has built upon the earlier pioneering contributions. Therefore, an important contribution of the present article is that, by reporting data specifically for a Canadian sample, it paves the way for future research on learning environment in Canada.

INITIAL DEVELOPMENT

The initial development of the new instrument, called the Science Laboratory Environment Inventory (SLEI), was guided by five criteria:

1. *Consistency with the literature on laboratory teaching.* A review of literature identified dimensions considered important in the unique environment of the science laboratory class (Hofstein & Lunetta, 1982; Woolnough, 1991).
2. *Consistency with instruments for non-laboratory settings.* Guidance was obtained by examining all scales in existing classroom environment instruments for non-laboratory settings (Fraser, 1986).
3. *Coverage of Moos' general categories.* Scales provided coverage of the three general categories of dimensions identified by Moos (1974) for conceptualizing all human environments. These are "Relationship Dimensions" (the nature and intensity of personal relationships), "Personal De-

velopment Dimensions" (directions of personal growth and self-enhancement), and "System Maintenance and System Change Dimensions" (the extent to which the environment is orderly, clear in expectation, maintains control, and is responsive to change). Since a reasonably complete picture of environment includes Relationship Dimensions, Personal Development Dimensions, and System Maintenance and System Change Dimensions, the SLEI included scales in each of these categories.

4. *Salience to teachers and students.* Interviews with science teachers and students at the upper secondary and university levels showed that SLEI's dimensions and individual items were salient.
5. *Economy.* To achieve economy in terms of the time needed for answering and scoring, the SLEI had a relatively small number of reliable scales, each containing a small number of items.

Initially, the above criteria led to an instrument containing eight scales, although only the following five scales survived field-testing and item/factor analyses and appear in the final version. *Student Cohesiveness* assesses the extent to which students know, help, and are supportive of one another; *Open-Endedness* assesses the extent to which laboratory activities emphasize an open-ended, divergent approach to experimentation; *Integration* assesses the extent to which laboratory activities are integrated with non-laboratory and theory classes; *Rule Clarity* assesses the extent to which behaviour in the laboratory is guided by formal rules; and *Material Environment* assesses the extent to which laboratory equipment and materials are adequate. (The names of the three omitted scales were Teacher Supportiveness, Involvement, and Organization.) The Open-Endedness scale was included because, despite many calls for science laboratory classes to be more open-ended (for example, National Research Council, 1990), various studies have revealed that most laboratory activities are closed-ended (for example, Lumpe, 1991). By writing new items and rewriting existing ones, we redefined and modified scales selected from inventories for non-laboratory settings to suit them to science laboratory classes. We based further revisions of items on reactions from colleagues with expertise in questionnaire construction and in science teaching at the secondary and higher education levels, paying careful attention to suit item each for measuring both actual and preferred classroom environments.

DESCRIPTION OF THE SLEI

The initial version of the SLEI contained 72 items altogether, with 9 items in each of eight scales. However, extensive field-testing and instrument validation later led to a more economical and valid final version with 35 items, with 7 items in each of five of the original scales. Each item's response alternatives are Almost Never, Seldom, Sometimes, Often, and Very Often. The scoring direction is reversed for approximately half the items.

A typical item in the actual form of the Student Cohesiveness scale is: "Students in this laboratory class get along well as a group." The wording of the preferred version is almost identical except for the use of such words as "would." For example, the item "Our laboratory class has clear rules to guide student activities" in the actual version is reworded in the preferred version to read "Our laboratory class would have clear rules to guide student activities."

FIELD-TESTING AND VALIDATION

Samples

Field-testing of the original 72-item, eight-scale version of the SLEI involved six subsamples of upper secondary school students from six countries and six subsamples of university students from the same six countries, namely, Canada, Australia, the United States, England, Israel, and Nigeria. The total sample consisted of 5,447 students in 269 classes in 53 sites. The bottom of Table 1 shows the sample sizes separately for schools and universities and separately for the total sample and the Canadian sample.

Item Analysis

The first step in refining and validating the instrument involved item analysis procedures to identify items whose removal would enhance each scale's internal consistency (the extent to which items in the same scale measure the same dimensions) and discriminant validity (the extent to which a scale measures a unique dimension not covered by other scales in the instrument). Scale internal consistency was improved by removing items with low item-remainder correlations (that is, correlations between a certain item and the rest of the scale excluding that item), and discriminant validity was improved by removing any item whose correlation with its a priori assigned scale was lower than its correlation with any of the other scales in the original version of the SLEI.

The item analysis procedures were applied separately for the actual and preferred versions, and separately for school and university student samples, because it was important that the instrument be well suited to assessing either actual or preferred environment with either school students or university students. In addition, because we wished to establish the cross-national validity and applicability of the SLEI, the item analyses were performed separately for each of the six countries. This made a set of 24 separate item analyses (six countries, schools/universities, and actual/preferred versions) that needed to be examined simultaneously. If fact, an important feature of the instrument refinement process was that an item was omitted if (after taking into consideration the fact that the smaller sample sizes in a couple of countries could produce less dependable statistics) it displayed unsatisfactory statistical characteristics in any one particular country; clearly, it was important to evolve an instrument for which every item was suitable in every country.

Item analysis led to the successive deletion of 20 of the original 72 items to produce the interim 52-item, seven-scale version (with the original Involvement scale omitted altogether) described in Giddings and Fraser (1990). This 52-item version, whose scales had satisfactory internal consistency reliability and an acceptable level of scale independence (in each country, in actual and preferred versions, and for both school and university students), formed the starting point for the factor analyses described below.

Factor Analyses

The second major stage in refinement and cross-national validation of the SLEI involved factor analyses whose purpose was to examine further the internal structure of the set of 52 items that had survived the item analyses. Using SPSS, principal components analysis with varimax rotation generated orthogonal factors. We considered seven-, six-, and five-factor solutions.

Eight separate factor analyses were run for the cross-national sample and examined simultaneously. Because of possible differences between factor structures of the actual and preferred versions, or of structures of school and university student data, we ran these analyses separately. Because many applications of classroom environment instruments use the class mean, rather than individual results, as the unit of statistical analysis, we followed Sirotnik's (1980) advice and performed separate analyses for individual students and class means.

These factor analyses led us to delete the two original scales of Teacher Supportiveness and Organization because most of their items loaded appreciably on the same factor as items from the Integration scale. With the deletion of all items from these two scales, plus the removal of another two items from other scales, a 34-item, five-factor solution was chosen as optimal for the final version of the SLEI. (Because this 34-item version had seven items in every scale except Open-Endedness, one more item was added at the cross-validation stage.)

Factor loadings were examined for the total sample of 3,727 school students in 198 classes, and separately for the total sample of 1,720 university students in 71 classes, for actual and preferred versions, and for the individual student and the class mean as the unit of analysis.

With the individual as the unit of analysis for the actual version and for either the school or university student sample, each of the 34 items had a factor loading greater than 0.30 with its a priori scale and less than 0.30 with each of the other four scales. This pattern was similar for the preferred version, although the Material Environment scale overlapped somewhat with the Student Cohesiveness scale for both the school sample and the university sample.

TABLE 1

Internal Consistency Reliability (Alpha Coefficient) for Actual and Preferred Forms for Schools and Universities for Two Units of Analysis for Canadian and Total Samples

		Alpha reliability							
		Canada				*Total sample*			
	Unit of	*Schools*		*Univer-sities*		*Schools*		*Univer-sities*	
Scale	*analysis*	*A*	*P*	*A*	*P*	*A*	*P*	*A*	*P*
Student	Individual	.75	.63	.83	.70	.77	.72	.78	.73
cohesiveness	Class mean	.80	.81	.91	.77	.92	.89	.88	.81
Open-	Individual	.60	.54	.55	.56	.70	.60	.65	.60
endedness	Class mean	.82	.67	.69	.70	.81	.72	.76	.77
Integration	Individual	.80	.73	.88	.82	.83	.81	.91	.84
	Class mean	.95	.82	.95	.93	.95	.92	.98	.96
Rule	Individual	.76	.65	.81	.69	.75	.70	.76	.66
clarity	Class mean	.95	.81	.91	.83	.92	.85	.91	.88
Material	Individual	.79	.70	.72	.65	.75	.72	.72	.66
environment	Class mean	.94	.86	.81	.74	.88	.89	.79	.78
Sample	Individuals	282		323		3727		1720	
size	Classes	12		11		198		71	

For the four factor analyses with class mean as the unit of analysis, the factor structure obtained was very similar (except that higher percentages of variance were extracted and even larger factor loadings were observed). All items for the actual form for the school students sample, and the majority of items for the other three analyses, had factor loadings in excess of 0.40. Overall, the results attest to the factorial validity of the SLEI for applications involving either the individual or the class as the unit of analysis.

Analyses for the Canadian sample, using the individual as the unit of analysis, produced an almost identical factor structure. Because of the small sample size, we could not perform a meaningful factor analysis for class means for the Canadian sample.

The factor analysis results have several noteworthy features. First, each of the five factors in the final version was among the eight a priori dimensions in the original version, and every one of the 34 items in the final version is retained in exactly the same a priori scale to which it was assigned when the instrument was originally developed. Second, the same factor structure applies to the school and university data, to the actual and preferred versions, and to the use of either the individual or the class mean as the unit of analysis. Third, for each of the eight factor analyses, the factor loading for almost every item's a priori assigned scale was larger than 0.30 with the individual as the unit of analysis, and larger than 0.40 with the class mean as the unit of analysis, while the number of items with factor loadings greater than these on scales other than a priori assigned scales was relatively small. Fourth, the percentages of the total variance extracted by the five factors were relatively large in all cases. All this evidence strongly supports the factorial validity of the 34-item, five-scale version of the SLEI.

Internal Consistency Reliability

Table 1 reports the internal consistency (alpha reliability coefficient) for the refined 34-item version of form of the SLEI, with separate reports of the Canadian sample and the total six-country sample, for actual and preferred versions, for the school student and the university student samples, and for the use of the individual student and the class mean as the unit of analysis. Table 1 suggests that the refined version of each SLEI scale has acceptable internal consistency in all cases. As expected, reliability estimates are noticeably higher with class mean as the unit of analysis. Reliability values for the Canadian samples are comparable to those obtained using the total six-country samples.

Discriminant Validity

Data about discriminant validity were generated using the mean correlation of one scale with the other scales as a convenient index. Again, data are reported separately in Table 2 for the actual and preferred forms, for school and university samples, and for the use of the individual student and the class mean as the unit of analysis. Despite arbitrary criteria, the values in Table 2 are small enough to suggest that each SLEI scale has adequate discriminant validity for use in its actual and preferred forms, with either school or university students, and for both units of analysis.

TABLE 2

Discriminant Validity (Mean Correlation with Other Scales) and Ability to Differentiate between Classrooms for Schools and Universities for Two Units of Analysis for Total Sample

		Mean correlation with other scales				ANOVA results Eta^2	
	Unit of	Schools		Universities		Schools	Universities
Scale	analysis	A	P	A	P	A	P
Student	Individual	.34	.39	.24	.38	.21*	.26*
cohesiveness	Class mean	.39	.42	.26	.44		
Open-	Individual	.07	.13	.12	.10	.19*	.20*
endedness	Class mean	.11	.16	.19	.16		
Integration	Individual	.37	.39	.21	.34	.23*	.25*
	Class mean	.41	.32	.20	.39		
Rule	Individual	.33	.35	.18	.28	.21*	.34*
clarity	Class mean	.38	.39	.19	.37		
Material	Individual	.37	.41	.28	.36	.21*	.24*
environment	Class mean	.42	.45	.28	.45		

*$p<.001$

When we performed the same analyses for the Canadian samples, discriminant validity results were comparable to those shown in Table 2 for the total samples. The SLEI measures show distinct although occasionally overlapping aspects of classroom environment. But, the conceptual distinctions among scales have been vindicated through the orthogonal factor analyses and are important enough to justify retaining the five dimensions the refined instrument.

Ability to Differentiate Between Classrooms

Another desirable characteristic of the actual form of any classroom environment instrument is that it be capable of differentiating between the perceptions of students in different classrooms. That is, students in the same class should perceive it relatively similarly, while mean within-class perceptions should vary from classroom to classroom. This characteristic was explored for each scale of the actual version of the SLEI for the total sample of 3,727 school students, and separately for the total sample of 1,720 university students described previously. This involved performing for each scale a one-way ANOVA, with class membership as the main effect and using the individual as the unit of analysis. The results of these analyses, reported in Table 2, indicate that each scale differentiated significantly ($p<.001$) between classrooms for the sample of school students and for the sample of university students. The eta^2 statistic, which represents the amount of variance in environment scores accounted for by class membership, ranged from 0.19 to 0.23 for the school student sample, and from 0.20 to 0.34 for the university student sample. Moreover, when the Canadian data were analyzed separately, each SLEI scale was again found to differentiate significantly between students in different classrooms.

Predictive Validity

In past classroom environment research, it has been common to investigate associations between student outcomes and the classroom environment (Fraser, 1986). To permit investigation of the predictive validity (that is, the ability to predict student outcomes) of the actual version of the SLEI, the samples of school and university students completed a simple eight-item Likert-type questionnaire assessing students' attitude to science laboratory work. Simple and multiple correlations were used in estimating the association between students' attitudes and their perceptions on the actual form of the SLEI. Table 3 reports the results of the simple correlation analyses *(r)* and multiple correlation analyses *(ß)* separately for the total sample and the Canadian sample and separately for schools and universities. These results are reported separately for the individual and the class mean as the unit of analysis for the total sample, but only with the individual as the unit of analysis for the Canadian sample because of the relative smallness of the Canadian sample size for class means. Overall, the dimensions of the SLEI are positively related with student attitudes (with the exception that Open-Endedness was related negatively to attitudes for some of the analyses). In particular, more favourable student attitudes toward laboratory work were found in classes perceived to be higher in Student Cohesiveness and Integration. For example, with the class mean as the unit of analysis, simple correlations in excess of 0.6 were observed between Integration and attitudes for both school and university students.

TABLE 3

Simple and Multiple Correlation Analysis of Associations between Attitude to Laboratory Work and Classroom Environment

		Total sample				Canada			
	Unit of	Schools		Univer-sities		Schools		Univer-sities	
Scale	analysis	*r*	β	*r*	ß	*r*	ß	*r*	ß
Student	Individual	.52**	.10**	.11**	.07*	.29**	.13**	.27**	.08
cohesiveness	Class mean	.49**	.14*	.22*	.07				
Open-	Individual	-.31**	-.10**	-.10**	-.08**	-.05	.00	.12	.06
endedness	Class mean	-.15*	.01	.13	-.03				
Integration	Individual	.59**	.19**	.18**	.21**	.30**	.18**	.34**	..09
	Class mean	.67**	.54**	.65**	.64**				
Rule	Individual	.47**	.01	.04	-.06	.28**	.04	.08	.02
clarity	Class mean	.40**	.05	.09	-.05				
Material	Individual	.52**	.02	.03	-.11**	.26*	.02	.30**	-.06
environment	Class mean	.47**	.03	.05	-.01				
Multiple	Individual	.66**		.26**		.49**		.63**	
correlation	Class mean	.68**		.66**					
Sample	Individuals	3727		1720		282		323	
size	Classes	198		71		12		11	

*p<.05; **p<.01;

Cross-Validation with New Sample

Because improvements in scale statistics and structure achieved through conducting item and factor analyses and subsequently removing "faulty" items can be lost in subsequent administrations to new samples, we cross-validated the refined version of the SLEI using a new sample consisting of 1,480 senior high school chemistry students in 96 classes in 52 schools in Brisbane, Australia, and nearby areas (Fraser, Giddings, & McRobbie, 1991). Overall, the analyses for the cross-validation sample further supported the internal consistency reliability, discriminant validity, and factorial validity of the actual and preferred versions of the Class form of the SLEI when used with either the individual or the class mean as the unit of analysis. Also, the actual form again differentiated between perceptions of students in different classrooms.

CONCLUSION

This paper aims to stimulate and to facilitate in Canadian schools and universities future research and practical applications on psychosocial environment by describing the development of a new instrument, the Science Laboratory Environment Inventory (SLEI), which assesses five dimensions of the actual and preferred climate of science laboratory classes at the upper secondary school and higher education levels. Noteworthy features of the SLEI include its consistency with the literature, specific relevance to science laboratory classes, salience to science teachers and students, and economy of administration and scoring time.

The SLEI was field-tested and validated with cross-national samples consisting of 3,727 upper secondary school students in 198 classes and 1,720 university students in 71 classes from six countries (Canada, Australia, USA, England, Israel, and Nigeria). Item and factor analyses led to a refined version with satisfactory internal consistency reliability, discriminant validity, and factorial validity in both its actual and preferred versions, for use in either senior high school or university classrooms, and using either the individual or the class mean as the unit of analysis. As well, further analyses supported the ability of the SLEI to differentiate between the perceptions of students in different classrooms and to predict student outcomes. Canadian results are comparable to cross-national results. Another important step in the validation process involved cross-validation of the refined instrument with a new sample which consisted of 1,480 senior high school chemistry students in 96 classes.

We hope Canadian educational researchers and teachers will use the SLEI to pursue several research and practical applications analogous to those completed successfully in prior classroom environment research in non-laboratory class settings (Fraser, 1986; Fraser & Walberg, 1991). Because of the high cost of laboratory teaching and doubts about its effectiveness, researchers should consider the SLEI to monitor students' views of their laboratory classes, investigate the impact of laboratory environments on student outcomes, and provide a basis for improving these learning environments.

Classroom climate dimensions as assessed by the SLEI are likely, as in past research (Fraser, 1981), to provide useful process criteria of effectiveness in evaluating new and innovative approaches to laboratory teaching. Also, past research which has compared students' and teachers' perceptions of the same classroom environments (Fisher & Fraser, 1983) usefully could be replicated using the SLEI in laboratory class settings.

Furthermore, there is scope to use the SLEI in some of the recent lines of research and desirable new directions for classroom environment research identified by Fraser (in press). For example, it is desirable to break away from the tradition of separateness of the fields of classroom and school environment and to combine classroom and school environment measures in one study. Classroom environment ideas, including work with the SLEI, are of potential value for incorporation into teacher education programs and into the work of school psychologists. As ideas from the field of classroom environment already are being incorporated into teacher assessment schemes, the SLEI might provide some ideas and methods for tapping science teachers' competence in the very important area of laboratory teaching. Finally, recent research has made noteworthy progress toward the desirable goal of combining qualitative and quantitative methods in the same classroom environment study.

REFERENCES

Anderson, G.J. (1970). Effects of classroom social climate on individual learning. *American Educational Research Journal, 7,* 135–152.

Fraser, B.J. (1981). *Learning environment in curriculum evaluation: A review.* Oxford: Pergamon Press.

Fraser, B.J. (1986). *Classroom environment.* London: Croom Helm.

Fraser, B.J. (1989). Twenty years of classroom environment work: Progress and prospect. *Journal of Curriculum Studies, 21*, 307–327.

Fraser, B.J. (in press). Context: Classroom and school climate. In D. Gabel (Ed.), *Handbook of research on science teaching and learning.* New York: Macmillan.

Fraser, B.J., & Fisher, D.L. (1982). Predicting students' outcomes from their perceptions of classroom psychosocial environment. *American Educational Research Journal, 19,* 498–518.

Fraser, B.J., & Fisher, D.L. (1983). Use of actual and preferred classroom environment scales in person-environment fit research. *Journal of Educational Psychology, 75,* 303–313.

Fraser, B.J., & Fisher, D.L. (1986). Using short forms of classroom climate instruments to assess and improve classroom psychosocial environment. *Journal of Research in Science Teaching, 23,* 387–413.

Fraser, B.J., Giddings, G.J., & McRobbie, C.J. (1991, April). *Science laboratory classroom environments: A cross-national perspective.* Paper presented at annual meeting of American Educational Research Association, Chicago.

Fraser, B.J., & Walberg, H.J. (Eds.) (1991). *Educational environments: Evaluation, antecedents and consequences.* Oxford: Pergamon Press.

Gallagher, J.J. (1987). A summary of research in science education. *Science Education, 71,* 277–284.

Giddings, G., & Fraser, B.J. (1990, April). *Cross-national development, validation and use of an instrument for assessing the environment of science laboratory classes.* Paper presented at annual meeting of American Educational Research Association, Boston.

Haertel, G.D., Walberg, H.J., & Haertel, E.H. (1981). Socio-psychological environments and learning: A quantitative synthesis. *British Educational Research Journal, 7,* 27–36.

Hegarty, E. (1987). Science laboratory teaching. In M.J. Dunkin (Ed.), *International Encyclopedia of teaching and teacher education* (pp. 298–304). Oxford: Pergamon Press.

Hofstein, A., & Lunetta, V. (1982). The role of the laboratory in science teaching: Neglected areas of research. *Review of Educational Research, 52,* 201–207.

Layton, D. (1989). *Reconceptualizing science and technology education for tomorrow.* London: British Council.

Lumpe, A.T. (1991, April). *A content analysis of secondary biology laboratory activities.* Paper presented at annual meeting of National Association for Research in Science Teaching, Fontane, Wisconsin.

Moos, R.H. (1974). *The Social Climate Scales: An overview.* Palo Alto, CA: Consulting Psychologists Press.

National Research Council. (1990). *Fulfilling the promise: Biology education in the nation's schools*. Washington, DC: National Academic Press.

O'Reilly, R.O. (1975). Classroom climate and achievement in secondary school mathematics classes. *Alberta Journal of Educational Research, 21,* 241–248.

Randhawa, B.S. (1991). Structural links between achievement and contextual measures. In B.J. Fraser & H.J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 231–244). Oxford: Pergamon Press.

Sirotnik, K.A. (1980). Psychometric implications of the unit-of-analysis problem (with examples from the measurement of organizational climate). *Journal of Educational Measurement, 17,* 245–282.

Tobin, K. (1986). Secondary science laboratory activities. *European Journal of Science Education, 8,* 199–211.

Walberg, H.J. (1991). Improving school science in advanced and developing countries. *Review of Educational Research, 61,* 25–69.

Woolnough, B.E. (Ed.). (1991). *Practical science: The role and reality of practical work in school science*. Milton Keynes, UK: Open University Press.

Barry J. Fraser is in the Science and Mathematics Education Centre, Curtin University of Technology, GPO Box U 1987, Perth 6001, Western Australia, Australia, and Alan K. Griffiths is in the Department of Education, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X8.