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LEARNING ENVIRONMENT AND ATTITUDES ASSOCIATED WITH AN INNOVATIVE SCIENCE COURSE DESIGNED FOR PROSPECTIVE ELEMENTARY TEACHERS

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ABSTRACT. This study assessed the effectiveness of an innovative science course for improving prospective elementary teachers' perceptions of laboratory learning environments and attitudes towards science. The sample consisted of 27 classes with 525 female students in a large urban university. Changing students' ideas about science laboratory teaching and learning and creating more positive attitudes towards science were accomplished by using a guided open-ended approach to investigations, together with instructors who used cooperative learning groups to create a supportive environment. Ideas and attitudes prior to the course were assessed using a questionnaire focusing on the students' previous science laboratory courses, and these were compared to data collected at the end of the course. Students reported large and statistically significant improvements on all seven scales assessing the laboratory learning environment and attitudes towards science. The largest gains were observed for Open-Endedness and Material Environment (with effect sizes of 6.74 and 3.82 standard deviations, respectively). An investigation of attitude-environment associations revealed numerous positive and statistically significant associations in both univariate and multivariate analyses. In particular, the level of Instructor Support was the strongest independent predictor of student attitudes at two levels of analysis.

KEY WORDS: attitudes, laboratory instruction, learning environments, teacher education

Future elementary teachers often feel apprehension about teaching science, which is rooted in their phobia of the subject itself. For many, this fear of science grew out of their own science learning experience being dominated by rote memorization of vocabulary, mathematical abstraction, heavy reliance on textbooks and worksheets, and a dearth of relevant hands-on activities. This all-too-common traditional method of science instruction often disillusions and frustrates prospective elementary teachers who, as a result, tend to avoid science courses during their secondary school and tertiary education or take only the minimum required number of science courses for their degree. Unfortunately, a dislike of science can remain deeply embedded as prospective elementary teachers near the time to step into their own classrooms. Without a positive experience in a college science laboratory course, many future elementary

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teachers will avoid teaching science to their students altogether or relegate it to the back burner — particularly with the current pressure to improve standardized test scores in reading and mathematics. If science is taught, many elementary teachers teach it in the same didactic style that they themselves experienced. The cycle of absent or ineffective science instruction can continue unchecked for generations.

The course described in this article, *A Process Approach to Science*, is a component of a liberal studies undergraduate degree at a large urban university in the USA. Students usually take the course in their senior year and before beginning a teacher-preparation program. Three science laboratory courses serve as prerequisites: physical science, geology, and biology. The course, however, is *not* a science 'methods' course, but rather it is a capstone content course in which basic scientific principles and concepts in the physical, life, and earth sciences are re-emphasized from earlier courses.

Many students struggle with the prerequisite courses. The small group of students who fail one of these courses must take it again. Prerequisite courses are usually taught in a didactic fashion in large lecture halls, accompanied by old-fashioned 'bench-style' laboratories with cookbook experiments (rigid step-by-step procedures) that often do not coincide with lecture material. Laboratories are usually taught by a graduate teaching assistant. These traditional science courses, common throughout many universities, place a heavy emphasis on content, portray the view that a body of knowledge must be acquired, and allow very little time for investigating the processes of science (Tilgner, 1990).

A Process Approach to Science is not a typical laboratory course. It is taught in a hybrid laboratory/seminar room in which a guided open-ended approach to experimentation and investigation is used. Instructors actively encourage asking questions, being skeptical, using creativity, and learning cooperatively. Seven part-time and full-time instructors teach the course to about 250 students every semester. All instructors follow a similar syllabus and have considerable K–12 science teaching experience (average is 10.3 years). A standard textbook is not required. Students must read 25 articles that have been specifically selected, including ones from the National Science Teachers Association publications such as *Science and Children.* Students use *The Usborne Book of Science* (Beeson, Chisholm, Kent, Johnson & Ward, 1993) as a reference, as well as reading *A Beginner's Guide to Scientific Method* (Carey, 2004).

The seven instructors involved in A Process Approach to Science did not receive formal professional development related to the innovative approaches. However, these instructors did meet monthly to discuss and reflect upon various aspects related to instruction, assessment, and improvement of the course. For the innovative course, instructors taught lecture and laboratory components in an integrated way in the same room. For the traditional prerequisite course, lectures were given by experienced science professors while separate laboratory classes were led mainly by graduate assistants.

The learning environment of any classroom includes the intangible aspects that give the room a particular feel or tone (Fraser, 2001). Learning environment researchers do not evaluate the science teacher, textbook, curriculum, or physical design of a classroom or laboratory, but these important features naturally affect the learning environment. The learning environment can be sensed when a stranger spends only a few minutes in a classroom. The atmosphere in a science classroom might be charged with dozens of excited voices, anticipation, and a spirit of discovery. Or it could be cloaked with suppression, uncomfortable silence, and a humdrum feeling. Many prospective elementary teachers have experienced the latter during their own science education in secondary and tertiary institutions.

Although the field of learning environments research has a long and illustrious history involving a variety of questionnaires, this study is significant because only one past published study focused on a preservice teacher education program (Yarrow, Millwater & Fraser, 1997). This is the first study of prospective elementary teachers' views of an undergraduate science course, including a comparison of previous science laboratory courses. The objectives of this study were:

1. To develop valid and reliable measures of prospective elementary teachers':

   (a) perceptions of laboratory learning environments
   (b) attitudes towards science.

2. To assess the effectiveness of an innovative science course designed for prospective elementary teachers in terms of:

   (a) perceptions of laboratory learning environments
   (b) attitudes towards science.

3. To investigate associations between the laboratory learning environment and students' attitudes towards science.

Theoretical Background on Learning Environments Research

The history of learning environments research has its roots in the social sciences. Lewin (1936) proposed the formula, $B = f(P,E)$ in which Behavior (B) is a function of both the Person (P) and the Environment (E). Lewin also distinguished between *beta* press (a description of the environment as perceived by people themselves in an environment) and *alpha* press (a description of the environment as observed by a detached observer). There are many advantages in considering beta press, particularly in schools and classrooms, because an outside observer can miss important events and interactions. Murray (1938) applied Lewin's concepts of alpha and beta press to his needs-press model in which needs refers to an individual's motivation to achieve goals, while press describes how the environment either helps or hinders a person to meet their goals.

The first learning environment questionnaires for use in educational settings were developed in the late 1960s and early 1970s in the United States. The Learning Environment Inventory (LEI, Walberg & Anderson, 1968) was developed to evaluate the well-known Harvard Physics Project in terms of students' perceptions of their secondary physics classrooms. Simultaneously, Rudolf Moos at Stanford University began studying environments as diverse as psychiatric hospitals, university residences, conventional work sites, and correctional institutions. His studies eventually led him to schools where he subsequently developed the Classroom Environment Scale (CES, Moos, 1979; Moos & Trickett, 1974).

All of the early instruments assessed students' perceptions of the classroom environment as a whole or single entity. Stern, Stein & Bloom (1956) extended Murray's notion of beta press into *private* beta press (an individual's view of their environment) and *consensual* beta press (the shared view of a group as a whole), although the distinction between private and consensual press did not take root until the development of the Science Laboratory Environment Inventory (SLEI, Fraser, Giddings & McRobbie, 1992, 1993, 1995). This is an important consideration in classrooms because private and consensual beta press could, and often do, differ from each other.

The LEI, CES, SLEI and all learning environment instruments that followed were modeled on Moos' (1979) three basic categories for describing human environments based on a social ecological perspective: Relationship, Personal Development, and System Maintenance and Change dimensions. Moos' influence can still be seen in the modification of existing instruments (Fraser, 1998), and in the creation of new ones that reflect current educational trends such as a constructivist pedagogy (Constructivist Learning Environment Survey, CLES; Taylor, Fraser & Fisher, 1997), the use of laptop computers in classrooms (Raaflaub & Fraser, 2002), Internet and technology-enriched classrooms (Aldridge, Fraser, Fisher & Wood, 2002; van den Berg, 2004; Zandvliet & Fraser, 2004, 2005), distance-education learning environments (Walker & Fraser, 2005), and the development of online surveys (Trinidad, Fraser & Aldridge, 2004).

The What Is Happening In this Class? (WIHIC) questionnaire was developed by Fraser, McRobbie & Fisher, (1996) to combine important scales from past questionnaires with contemporary dimensions to bring parsimony to the field. The WIHIC has been found to be consistently reliable and valid across several subject areas and in several countries, such as science in Australia, Taiwan, Brunei, the United States, South Africa, and Canada (Aldridge & Fraser, 2000; Aldridge, Fraser & Huang, 1999; Aldridge, Laugksch, Seopa & Fraser, 2006; Zandvliet & Fraser, 2005), mathematics in Indonesia (Margianti, Aldridge & Fraser, 2004), and mathematics and geography in Singapore (Fraser & Chionh, 2000). Recently, a large cross-national validation of the WIHIC was conducted using confirmatory factor analysis (Dorman, 2003) with close to 4,000 mathematics and science high school students from Australia, the UK, and Canada.

From its genesis in the United States, learning environments research spread to Australia and then to The Netherlands with the development of the Questionnaire on Teacher Interaction (QTI, Fraser & Walberg, 2005; Wubbels & Levy, 1993). More recently, Asian researchers have cross-validated several questionnaires in English-speaking countries (Singapore and Brunei), but also have completed the laborious task of translating, back-translating and validating these instruments in the Chinese, Indonesian, Korean, and Malay languages (Fraser, 2002; Kim, Fisher & Fraser, 2000; Scott & Fisher, 2004).

Whereas early research on attitudes and classroom learning environments used predominantly quantitative methods, combining quantitative and qualitative methods is a distinctive thrust of current research (Tobin & Fraser, 1998). Researchers have complemented their large-scale questionnaire surveys with focused classroom observations and interviews in order to uncover rich, contextual understandings of learning environments and also cultural differences and similarities in the science learning environment between countries (Aldridge & Fraser, 2000; Goh & Khine, 2000; Wallace, Venville & Chou, 2002; Zandvliet & Fraser, 2005).

The present study also included the collection of qualitative data in the form of semi-structured interviews with 38 prospective elementary teachers enrolled in the first author's classes. However, only quantitative results are reported in this article.

Students' attitudes have frequently been assessed and investigated in conjunction with the classroom learning environment. Studies have consistently found strong associations between positive attitudes and positive classroom learning environments, and moderate associations between learning environment and cognitive achievement (Fraser, 1998; Haertel, Walberg & Haertel, 1981; McRobbie & Fraser, 1993). Hofstein & Walberg, (1995) found that a positive learning environment specifically in a science laboratory can lead to improved attitudes towards science. Hofstein and Walberg's study and others were successful in emphasizing the important role of attitudes in learning science, but offered few suggestions on *how* to change negative attitudes into positive attitudes, and to create positive learning environments. Instructors at all levels often see their students performing poorly in science but do not know how to make positive changes in their classrooms.

Materials and Methods

Data Sources

Data collection involved 525 students from 27 classes of A Process Approach to Science. Class sizes were small, ranging from 14 to 32 students and with an average of 24.5 students, during the four semesters when data were collected. In a typical class, the majority of students are female with only one or two males. To control for the variable of gender, male students were eliminated from the sample, although they did not realize this and were asked to complete the survey also. The students' average age was approximately 24 years, with a median age of 23 years and a range from 20 to 52 years.

Instruments

The learning environment was assessed with six scales. The first four eight-item scales, namely, Student Cohesiveness, Instructor Support, Investigation, and Cooperation, came from the What Is Happening In this Class? (WIHIC, Aldridge et al., 1999), while the two seven-item scales named Open-Endedness and Material Environment came from the Science Laboratory Environment Inventory (SLEI, Fraser et al., 1995).

Participants were asked to consider how often each practice or situation took place and to choose a response from a five-point frequency scale (Almost Never, Seldom, Sometimes, Often and Very Often). Four of the items taken from the SLEI are 'reverse-scored'. Traditionally, negatively-worded and reverse-scored items are included to reduce the likelihood of participants biasing their responses to either end of the response scale (Taylor et al., 1997), although one study found that reverse-scoring is not effective and recommended that directly-worded statements be used with bi-directional response options (Barnette, 2000). The meaning of the six learning environment scales is clarified in Table I, which contains the name of the scale, its description, and a sample item for each dimension.

The Test of Science-Related Attitudes (TOSRA, Fraser, 1981) has been frequently used to assess students' attitudes, both in its original form with seven scales and 70 items and in shorter modified forms, and in modified form to assess attitudes to mathematics (Quek, Wong & Fraser, 2005; Spinner & Fraser, 2005). In addition to the six learning environment scales, eight items were selected from TOSRA's Enjoyment of Science Lessons scale. A sample item is: "The lessons made me interested in science." Although the original TOSRA has seven separate and overlapping scales (Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science and Career Interest in Science), only the Enjoyment of Science Lessons was used in our study because what it measures (enjoyment or satisfaction) was most salient to the aims of both the innovative and comparison courses. The total number of items in the combined learning environment and attitude survey was 54. The Appendix includes a listing of all items in the seven learning environment and attitude scales.

The prospective elementary teachers were asked to complete the questionnaire on two occasions. On the first day of class, the researcher administered the survey to her own classes and then to the other instructors' classes during 2002 and 2003. An important point that the researcher stressed during this first administration of the survey was that it should be completed with the student's *previous* science laboratory course in mind, whether it was at the same university or at another campus. In the majority of cases, the students' last laboratory course was one of the three prerequisite courses mentioned earlier. Participants also recorded the name of their previous science laboratory course, along with their student identification number, age and gender. If their previous science course consisted of both a lecture and a laboratory component, which was the most common scenario, they were instructed to focus on

TABLE I

Descriptive information for each learning environment scale

Scale name	Description	Sample item
Student Cohesiveness	Extent to which students know, help and are supportive of one another.	I worked well with other students. (+)
Instructor Support	Extent to which the instructor helps, befriends, trusts, and shows interest in students.	The instructor's questions helped me to understand. (+)
Investigation	Emphasis on the skills and processes of inquiry and their use in problem solving and investigation.	I found out answers to questions by doing investigations. (+)
Cooperation	Extent to which students cooperate rather than compete with one another on learning tasks.	When I worked in groups, there was teamwork. (+)
Open-Endedness	Extent to which the laboratory activities emphasize an open-ended divergent approach to experimentation.	The instructor decided the best way for me to carry out the laboratory experiments. (−)
Material Environment	Extent to which the laboratory equipment and materials are adequate.	The laboratory equipment that I used was in poor working order. (−)

+ Items designated (+) are scored 1, 2, 3, 4 and 5, respectively, for the responses Almost Never, Seldom, Sometimes, Often and Almost Always

− Items designated (−) are scored 5, 4, 3, 2 and 1, respectively, for the responses Almost Never, Seldom, Sometimes, Often and Almost Always the laboratory section of the course. The second time when the survey was given to students was at the completion of the course. This time, it was stressed that students were responding to the survey's statements with A Process Approach to Science in mind.

Data Analysis

Factor analysis was conducted for the six scales of the learning environment questionnaire using the principal axis factoring method for extraction. During factor rotation, factor loadings less than 0.4 were not reported. Only items with factor loadings greater than 0.4 on their own scale for *either* the students' previous science course or for A Process Approach to Science, or both, were used to calculate the internal consistency reliability (Cronbach alpha coefficient), the discriminant validity (mean correlation with other scales), and each scale's ability to differentiate between classrooms (ANOVA results). Calculations for two units of analysis, the individual and the class mean, were conducted. Alpha reliability was determined for the Enjoyment of Science Lessons scale from the TOSRA, also using two units of analysis. As the ability to differentiate between classrooms is not relevant for an attitude scale, the ANOVA performed for learning environment scales was not performed and reported for the Enjoyment scale.

To determine differences between prospective elementary teachers' previous laboratory course and A Process Approach to Science, several analyses were performed. First, the average item mean and the average item standard deviations were calculated for each of the seven scales, using the class mean as the unit of analysis. Secondly, the effect size was calculated — a measure of the strength or magnitude of any differences between the previous science laboratory course and A Process Approach to Science. This was calculated by dividing the difference between the average item means for the two groups by the pooled standard deviation (Thompson, 1998).

A paired-samples *t*-test was conducted to ascertain the statistical significance of any differences between instructional methods for each scale. Because multiple *t*-tests were conducted and the possibility of a Type I error existed (differences appear statistically significant but might not be in reality), a modified Bonferroni procedure was conducted as well (Holland & Copenhaver, 1988; Jaccard & Wan, 1996). This procedure guards against Type I error inflation and provides a more conservative measure of statistical significance. The Bonferroni procedure involves ranking the *t*-values from most significant to the least significant, and dividing the most significant *p*-value by the total number

TABLE II

Factor loadings for learning environment scales

Item no.	Factor loadings											
	Student cohesiveness		Instructor support		Investigation		Cooperation		Open-endedness		Material environment	
	Previous course	A Process Approach to Science	Previous course	A Process Approach to Science	Previous course	A Process Approach to Science	Previous course	A Process Approach to Science	Previous course	A Process Approach to Science	Previous course	A Process Approach to Science
1	0.70	0.70										
2	0.52	0.44										
3	0.62	0.71										
4	0.74	0.72										
5	0.66	0.68										
6	0.52	0.53										
7	0.73	0.76										
8	0.46	0.49										
9			0.77	0.75								
10			0.81	0.86								
11			0.82	0.82								
12			0.77	0.81								
13			0.83	0.81								
14			0.80	0.80								
15			0.71	0.69								
16			0.73	0.69								
17					0.72	0.72						
18					0.66	0.64						

19					0.73	0.80						
20					0.65	0.67						
21					0.70	0.73						
22					–	0.71						
23					0.76	0.79						
24					0.74	0.74						
25							0.70	0.61				
26							0.60	–				
27							0.70	0.59				
28							0.74	0.57				
29							0.70	0.75				
30							0.80	0.75				
31							0.78	0.71				
32							0.74	0.76				
33									0.54	0.49		
34									0.63	0.58		
35									–	0.62		
36									0.67	0.68		
37									0.66	0.71		
39									0.56	0.42		
40											0.60	0.67
42											0.63	0.67
43											0.67	0.54
45											0.51	–
46											0.67	0.56
% Variance	4.26	4.22	24.15	25.29	5.73	8.80	10.79	6.60	3.45	3.27	3.17	2.74
Eigenvalue	.96	1.94	11.11	11.63	2.64	4.05	4.96	3.04	1.59	1.51	1.46	1.26

Factor loadings < 0.40 omitted

N = 525 female prospective elementary teachers in 27 classes in Southern California

TABLE III

Internal consistency reliability (Cronbach alpha Coefficient), discriminant validity (mean correlation with other scales) and ability to differentiate between classrooms (ANOVA results) for two units of analysis for science learning environment and attitude scales

Scale	No. of items	Unit of analysis	Alpha reliability		Mean correlation with other scales		ANOVA Eta^2	
			Previous course	A Process Approach to Science	Previous course	A Process Approach to Science	Previous course	A Process Approach to Science
Learning Environment								
Student Cohesiveness	8	Individual	0.86	0.85	0.30	0.30	0.07	0.14**
		Class mean	0.88	0.92	0.54	0.42		
Instructor Support	8	Individual	0.94	0.95	0.32	0.34	0.04	0.23**
		Class mean	0.95	0.98	0.46	0.37		
Investigation	8	Individual	0.89	0.92	0.36	0.34	0.10**	0.12**
		Class mean	0.91	0.96	0.50	0.36		

Cooperation	8	Individual	0.92	0.67	0.26	0.34	0.06	0.11**
		Class mean	0.93	0.82	0.40	0.40		
Open-Endedness	6	Individual	0.80	0.80	0.27	0.28	0.07*	0.09*
		Class mean	0.85	0.87	0.48	0.46		
Material Environment	5	Individual	0.75	0.69	0.15	0.17	0.04	0.08*
		Class mean	0.71	0.69	0.17	0.22		
Attitude								
Enjoyment of Science	8	Individual	0.95	0.93				
Lessons		Class mean	0.96	0.98				

$^{*}p < 0.05$, $^{**}p < 0.01$

The sample consisted of 525 female prospective elementary teachers in 27 classes

The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership of tests performed (*n*). If the resulting *p*-value is less than the desired alpha (0.05 or 0.01), the difference is still considered significant. The second difference is considered significant if the resulting *p*-value is less than the desired alpha after dividing by *n-1*. This procedure is continued for each successive *p*-value by dividing by *n-k* until a statistically nonsignificant result is obtained, thereby guaranteeing that the remaining values are also nonsignificant.

To explore associations between the learning environment and attitudes towards science, simple correlation and multiple regression analyses were conducted using both the individual and class mean as units of analysis. Regression coefficients were also used to identify which individual learning environment scales were significantly related to student attitudes when the other five environment scales were mutually controlled.

Results

Questionnaire Reliability and Validity

The factor analysis resulted in only one item from the Open-Endedness scale and two items from the Material Environment scale being omitted from further analyses (Items 38, 41, and 44 — see Appendix). This was based on the decision to exclude any item that did not have a factor loading of 0.40 or greater on its a priori scale and less than 0.40 on all other environment scales. Table II reports the factor loadings for the remaining 43 items, as well as the percentage variance and eigenvalue for each scale.

The remaining 43 items were used for all other analyses. Table III shows that the Cronbach alpha reliability for the learning environment and attitude scales ranged from 0.67 to 0.98. The highest alpha coefficients were for Instructor Support and attitude (Enjoyment of Science Lessons), using the class mean as the unit of analysis. Both of these scales had alpha coefficients of 0.98. The mean correlation values with other learning environment scales (an index of discriminant validity) ranged from 0.15 to 0.54. In addition, all six learning environment scales significantly differentiated ($p < 0.05$) between classes (results of ANOVA with class membership as the independent variable) taught by the various instructors. The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares and represents the proportion of variance accounted for by class membership) ranged from 0.08 to 0.23 for different learning environment scales (Table III). The findings for internal consistency reliability, discriminant validity, and ability to differentiate between classrooms replicate previous research findings, and attest to the robustness of the learning environment. The attitude scale also had very good internal consistency reliability for two units of analysis (but the ability to differentiate between classrooms is not relevant to an attitude scale).

Comparing Previous Science Laboratory Courses and a Process Approach to Science

Descriptive statistics comparing participants' previous science laboratory course and A Process Approach to Science, using the class mean as the unit of analysis, are provided in Table IV for each learning environment and attitude scale. Figure 1 compares the two courses in terms of the average item mean for each learning environment and attitude scale. Table IV indicates that the average item mean for all seven scales was larger for A Process Approach to Science than for the previous course. The between-course difference in average item means ranged from 0.31 for Student Cohesiveness to 1.55 for Open-Endedness. Four of the scales showed an average between-course difference in average item mean close to or over 1.00 — Instructor Support (0.94), Investigation (0.98), Open-Endedness (1.55), and Enjoyment of Science Lessons (0.97).

The last column of Table IV reports the results of *t*-tests for the statistical significance of differences between the two instructional groups. As explained previously, the class mean was used as the unit of statistical analysis and the Bonferroni correction was used to reduce the risk of Type I errors. Table IV shows that differences between the two instructional groups were statistically significant ($p < 0.01$) for all seven learning environment and attitude scales.

In the second column of Table IV, the between-group difference in the average item means on each scale is expressed as an effect size (i.e., the number of standard deviations) as recommended by Thompson (1998). Table IV shows that the effect size for between-course differences was dramatic for all learning environment and attitude scales when the class mean was used as the unit of analysis. Effect sizes for the learning environment scales ranged from 1.51 standard deviations for Student Cohesiveness to 6.74 standard deviations for Open-Endedness. The Enjoyment of Science Lessons scale had an effect size of 2.98 standard deviations for differences between courses. These large effect sizes attest to the educational significance or importance of the differences between the two instructional groups.

TABLE IV

Average item mean, average item standard deviation, and differences (effect size and *t*-test for paired samples with Bonferroni correction) for the previous science course and for A Process Approach to Science for Learning Environment and Attitude scales using the class mean as the unit of analysis

Scale	Average item mean		Average item standard deviation		Difference	
	Previous course	A Process Approach to Science	Previous course	A Process Approach to Science	Effect size	*t*
Learning Environment						
Student Cohesiveness	4.13	4.44	0.20	0.21	1.51	7.32**
Instructor Support	3.26	4.20	0.23	0.40	2.98	12.91**
Cooperation	4.39	4.72	0.17	0.16	2.00	7.78**
Investigation	3.43	4.41	0.30	0.22	3.77	15.97**
Open-Endedness	2.30	3.85	0.24	0.22	6.74	34.54**
Material Environment	3.77	4.40	0.16	0.17	3.82	15.20**
Attitude						
Enjoyment of Science Lessons	3.09	4.06	0.27	0.38	2.98	15.06**

**$p < 0.01$(Using modified Bonferroni procedure with seven tests)
$N = 525$ female prospective elementary teachers in 27 classes

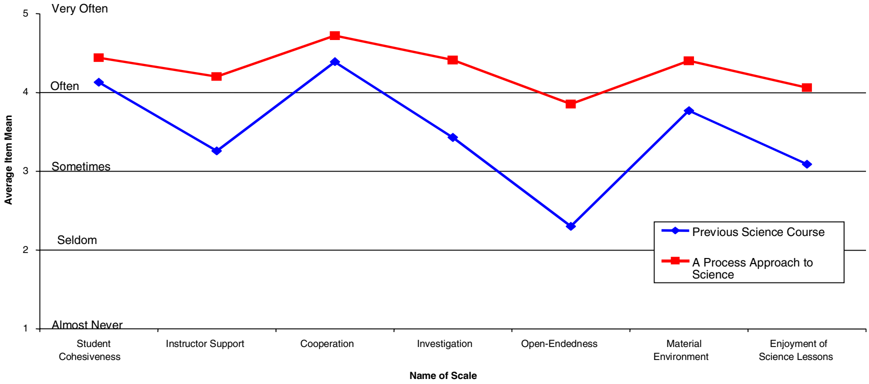

Figure 1. Comparison of previous science courses and A Process Approach to Science in terms of average item means for learning environment and attitudes scales

TABLE V

Simple correlation and multiple regression analyses for associations between the Learning Environment and Enjoyment of Science Lessons scales using two units of analysis

		Attitude-Learning Environment Association	
Scale	Unit of analysis	r	β
Student Cohesiveness	Individual	0.17**	−0.06
	Class	0.04	−0.10
Instructor Support	Individual	0.61**	0.51**
	Class	0.75**	0.87**
Investigation	Individual	0.35**	0.07
	Class	0.18	0.08
Cooperation	Individual	0.22**	−0.01
	Class	0.32	−0.14
Open-Endedness	Individual	0.36**	0.12**
	Class	0.28	−0.22
Material Environment	Individual	0.34**	0.20**
	Class	0.44*	0.26
Multiple Correlation (R)	Individual		0.66**
	Class		0.82**

*$p < 0.05$, **$p < 0.01$
$N = 525$ female prospective elementary teachers in 27 classes

Associations Between Learning Environment and Attitude

Attitude-learning environment associations, based on simple correlation and multiple regression analyses, are reported in Table V for two units of analysis (the student and the class mean). Simple correlations (r) describe the bivariate associations between Enjoyment of Science Lessons and each of the six learning environment scales (but does not hold the other five learning environment scales constant). With the individual as the unit of analysis, Table V shows that the simple correlation was statistically significant ($p < 0.01$) for all six learning environment scales. With the class mean as the unit of analysis, only the two learning environment scales of Instructor Support ($r = 0.75$, $p < 0.01$) and Material Environment ($r = 0.44$, $p < 0.05$) were significantly correlated with the Enjoyment of Science Lessons scale. For each unit of analysis, the simple correlation between Instructor Support and Enjoyment of Science Lessons was the highest of all the six learning environment scales.

The multiple regression analysis provides a test of the combined influence of all six learning environment scales on the Enjoyment of Science Lessons scale. Table V indicates a positive and statistically significant ($p < 0.01$) multiple correlation for both units of analysis. The values of the multiple correlation, of 0.66 with the individual unit of analysis and 0.82 for class means, can be considered high.

To determine which specific learning environment scales account for most of the variance in the Enjoyment of Science Lessons scale, standardized regression weights were also examined. The regression coefficient (β) indicates the strength of the association between each learning environment scale and attitudes when the five other learning environment scales are mutually controlled. Table V indicates that with the individual as the unit of analysis, the scale of Instructor Support had the largest independent influence ($\beta = 0.51$, $p < 0.01$) on Enjoyment of Science Lessons, although Open-Endedness and Material Environment were also significant independent predictors ($p < 0.01$). For the class mean as the unit of analysis, only Instructor Support was a statistically significant independent predictor of Enjoyment of Science Lessons scores ($p < 0.01$).

Discussion

Learning Environment

This study revealed large and statistically significant differences between students' previous science laboratory course and A Process Approach to

Science for all learning environment and attitude scales. The greatest difference was for Open-Endedness, which had an effect size of 6.74 standard deviations. Prospective elementary teachers rated the level of Open-Endedness in their previous laboratory course the lowest of all scales — the average item mean for this scale was 2.30 (i.e., Open-Endedness occurred 'seldomly'), which replicates a large cross-national study involving over 5,000 university and high school students in six countries (Fraser et al. 1995). When Fraser et al. (1995) asked students what they *prefer*, it is interesting to note that students preferred a more favorable laboratory environment with regard to all scales except Open-Endedness. Although we did not ask prospective elementary students about the level of Open-Endedness which they preferred, they did rate the *actual* level of Open-Endedness in A Process Approach to Science with an average item mean of 3.85 (indicating that an open-ended divergent approach to experimentation occurred at a frequency nearing 'often').

A high mean for Open-Endedness is unusual. Open-Endedness can come in various degrees, although earlier studies did not discuss any subtle distinctions between levels of Open-Endedness. Colburn (2000) describes three levels of inquiry: structured, guided, and open. In A Process Approach to Science, activities are initiated by the instructors and students who choose their own variations of researchable questions, procedures, and equipment. Multiple solutions to a problem are encouraged. Therefore, instructors use predominantly guided inquiry or guided open-endedness. Science instructors and students in earlier studies could have experienced open-endedness at only two levels — 'structured open-endedness' in which the teacher makes all the decisions and uses a laboratory manual or worksheet (therefore, not really open-ended at all); or 'open-open-endedness' in which students make all the decisions (e.g., science fair projects). Students who have rarely experienced open-open-endedness laboratory environments can feel a certain amount of anxiety. Perhaps this anxiety and discomfort contribute to the observed phenomena in earlier studies of both high school and university students *preferring* less open-endedness. Yet, "the discomfort generated by learning to do unfamiliar things may, in fact, be a critical mechanism for growth" (Joyce, 1991, p. 73). With the Enjoyment of Science Lessons scale having an average item mean of 4.06 (i.e., students 'often' looked forward to lessons, felt that lessons were fun and not boring, and found that lessons made them interested in science), it seems likely that guided open-endedness provides a comfortable and safe environment for learning to take place, and capitalizes on how future elementary teachers learn science best at this point in their science education.

For previous science courses, students perceived practices that were described in two scales — Instructor Support and Investigation — as occurring only sometimes. Students perceived that their previous laboratory course had an instructor who only ‘sometimes’ helped, trusted or showed an interest in them, and only sometimes emphasized the skills involved in the processes of inquiry and problem solving. This again replicates findings from past studies. Scores for these two scales were quite different for the two courses, with effect sizes for between-course differences of 2.98 and 3.77 standard deviations, respectively. The average item mean for A Process Approach to Science was 4.20 for Instructor Support and 4.41 for Investigation. Rather than providing a ‘cookbook’ method for investigations, instructors encouraged their students to think for themselves as they learned about the processes of science.

The scale of Material Environment had an average item mean of 3.77 and of 4.40, respectively, for previous science courses and A Process Approach to Science. This difference can be considered large as indicated by the effect size of 3.82 standard deviations. It appears that prospective elementary teachers found that a hybrid-style classroom, where laboratory and seminar are combined, provides a more favorable learning environment. Most often during A Process Approach to Science, students found that the classroom was not crowded, supplies were readily available, equipment was in good working order, and there was enough room for both individual and group work. With an average class size of 24.5 students, this finding was not surprising. These results seem to indicate that it is not necessary to have separate laboratory and lecture components to a science course, particularly for students who might not like science and/or are non-science majors.

Attitudes Towards Science

Prospective elementary teachers’ rated the items on the Enjoyment of Science Lessons scale for their previous laboratory course with an average item mean of 3.09. This indicates that looking forward to lessons, feeling that lessons were fun and not boring, and considering that lessons made them interested in science occurred only ‘sometimes’. However, students enjoyed A Process Approach to Science lessons ‘often’ as reflected in an average item mean of 4.06 on the Enjoyment of Science Lessons, as well as an effect size of 2.98 standard deviations for between-course differences. Whether or not these attitudes remain positive over time, particularly when these students become practicing elementary teachers in their own classrooms, is unknown. Many factors undoubtedly would affect their attitude *after* the course, such as the learning environment of their science methods course (if they take such a course), the university where they earn their teaching credential, the amount of time in between the course and beginning a teacher credentialing program and between completing the program and finding a teaching position, and the value placed on science education by the school, other teachers, and administrators.

Associations Between Learning Environment and Attitudes

Correlations between student attitudes and learning environment were positive for all learning environment scales, thus confirming the link between a favorable learning environment and positive student attitudes found in considerable prior research (Fraser, 1998). The multiple correlation for the combined influence of all six learning environment scales on attitude was high ($R = 0.66$ for individuals and 0.82 for class means) and statistically significant. The standardized regression weights showed that Instructor Support had the strongest unique relationship with attitudes. Perhaps, if instructors of traditional courses were made aware of these results, they might develop innovative ideas about how they can improve their courses. A small action-research study, conducted by one or two instructors, could provide a welcome opportunity to try an intervention specifically aimed at improving students' perceptions of Instructor Support.

Limitations

The major limitation of this study was internal validity. The first author was not only the primary researcher but also the instructor for six of the 27 classes (22%). One disadvantage of being a researcher-instructor is that it is difficult to 'refrain from teaching'. In fact, data from all of the instructors' classes can be subject to biasing influences such as 'demand characteristics' (participants respond in accordance with their perceptions of the expectations of the research and their instructors) (Hersen & Barlow, 1976). We know that people typically provide socially acceptable responses that might not be valid (Anderson, 1998). Also, on the first day of classes, students completed the questionnaire based on their previous laboratory class — a 'retrospective' approach that might have affected the quality of responses.

Second, in terms of external validity, it is probable that the findings could be generalized to many other undergraduate laboratory science courses. It would be inappropriate, however, to generalize the findings to other populations of students (e.g., males) at the tertiary level, graduate science course, or other countries. Using only female students created a limitation in that the findings can only be generalized to courses and/or programs that are also dominated by female students. Nevertheless, the learning environment scales used in our study have been validated and used with university students in several countries outside the United States (Fraser et al., 1992, 1995; Margianti et al., 2004). Therefore, it might be possible to tentatively generalize the findings outside of the United States to include tertiary female students with similar sample characteristics and comparable undergraduate laboratory science courses.

Third, a comprehensive assessment of attitudes towards science was constrained because only one attitude scale was used.

Conclusions

Although learning-environments research has had a long and illustrious history for 35 years, very few studies have involved teacher-preparation programs. Our study is distinct in that it investigated perceptions of the psychosocial learning environment and attitudes towards science among female prospective elementary teachers enrolled in an innovative science course at a large urban university in Southern California. We found large and statistically significant differences between a previous science laboratory course compared to A Process Approach to Science in terms of perceptions of the learning environment and attitudes to science. Positive gains were revealed on all six learning environment scales — Student Cohesiveness, Instructor Support, Cooperation, Investigation, Open-Endedness, and Material Environment, as well as for Enjoyment of Science Lessons. Associations between attitude and learning environment were high, particularly for the Instructor Support scale when the five other scales were controlled.

This study replicates with university students past research at the school level that has attested to: the validity of the WIHIC (Dorman, 2003; Aldridge & Fraser, 2000; Zandvliet & Fraser, 2005); the usefulness of learning environment dimensions as process criteria in the evaluation of educational programs (Fraser, 1998; Spinner & Fraser, 2005); and the existence of associations between students' attitudes and the nature of the classroom environment (McRobbie & Fraser, 1993; Quek et al., 2005; Wong & Fraser, 1996).

In terms of teacher-preparation programs at the elementary level, our study has implications for both the future teaching practice of elementary teachers and the learning of their future students. If beginning elementary teachers harbor a phobia or dislike of science, these beliefs will be passed on to their students. If beginning elementary teachers do not have a positive experience during any of their undergraduate science courses, coupled with pressures to improve standardized test scores in mathematics and reading, science is likely to be the first subject to be discontinued by teachers. Our study suggests that, with a positive experience in a laboratory course designed specifically for future teachers, elementary teachers are more likely to teach science to their own students and in the same open-ended, divergent style that they experienced during A Process Approach to Science.

Taking A Process Approach to Science might be the only time when students experience guided-open-endedness, supportive instructors, and have an enjoyable time in a science course. It is important for prospective elementary teachers (but probably also important for *all* students) that class sizes are small so that instructors can be personable and supportive. This can make a large and positive impact on students' attitudes towards science. Conducting a science course in a hybrid laboratory/seminar classroom also seems to contribute to students' positive perceptions of the learning environment. This has obvious implications for how most science courses are currently structured with students having separate lessons in a large lecture hall and a laboratory that is not conducive to cooperative learning simply because of its layout. Ideally, prospective elementary teachers also need to have a good student teaching experience and to be placed in a school that values science education. Only after all these building blocks are in place, can future elementary school children have a chance to enjoy science as their teachers did.

Fraser (1998) observes that, despite extensive research into classroom learning environments, the take-up of learning environment ideas and questionnaires among teachers and other practitioners has been limited. Therefore, an important contribution of our study is that, by validating a widely-applicable and economical learning environment questionnaire (the WIHIC) with a sample of university students, there is now considerable scope for university instructors to use the WIHIC to assess students' perceptions of their classroom learning environments and to follow established action-research techniques to guide improvements in these learning environments (Aldridge, Fraser & Sebela, 2004; Fraser & Fisher, 1986; Yarrow et al., 1997).

Appendix

TABLE VI

Items in Science Learning Environment & Attitude Scales

Student Cohesiveness

1. I made friends among students.
2. I knew other students.
3. I was friendly to other students.
4. Other students were my friends.
5. I worked well with other students.
6. I helped other students who were having trouble with work.
7. Students liked me.
8. I got help from other students.

Instructor Support

9. The instructor took a personal interest in me.
10. The instructor went out of his/her way to help me.
11. The instructor helped me when I had trouble with the work.
12. The instructor considered my feelings.
13. The instructor talked with me.
14. The instructor was interested in my problems.
15. The instructor moved about the class to talk with me.
16. The instructor's questions helped me to understand.

Investigation

17. I carried out investigations to test my ideas.
18. I was asked to think about the evidence for statements.
19. I carried out investigations to answer questions coming from discussions.
20. I explained the meaning of statements, diagrams and graphs.
21. I carried out investigations to answer questions that puzzled me.
22. I carried out investigations to answer the instructor's questions.
23. I found out answers to questions by doing investigations.
24. I solved problems by using information obtained from my own investigations.

Cooperation

25. I cooperated with other students when doing assignment work.
26. I shared my books and resources with other students when doing assignments.
27. When I worked in groups, there was teamwork.
28. I worked with other students on projects.
29. I learned from other students.
30. I worked with other students.
31. I cooperated with other students on class activities.
32. Students worked with me to achieve class goals.

Open-Endedness

33. There was opportunity for me to pursue my own interests.
34. I was required to design my own experiments to solve a given problem.
35. Other students collected different data than I did for the same problem.
36. I was allowed to go beyond the regular laboratory exercises and do some experimenting on my own.
37. I did different experiments than some of the other students.
38. The instructor decided the best way for me to carry out the laboratory experiments.
39. I decided the best way to proceed during laboratory experiments.

Material Environment

40. I found that the laboratory was crowded when I was doing experiments.
41. The equipment and materials that I need for laboratory activities were readily available.
42. I was ashamed of the appearance of the laboratory.
43. The laboratory equipment that I used was in poor working order.
44. I found that the laboratory was just the right temperature to work in.
45. The laboratory was an attractive place for me to work in.
46. My laboratory had enough room for individual and group work.

Attitude

47. I looked forward to lessons.
48. Lessons in the class were fun.
49. I disliked lessons in the class.
50. Lessons in the class bored me.
51. The class was one of the most interesting college classes.
52. I enjoyed lessons in the class.
53. Lessons in the class were a waste of time.
54. The lessons made me interested in science.

Items 38, 40, 42, 43, 49, 50, and 53 are reverse-scored

The frequency-response alternatives for each item are Almost Never, Seldom, Sometimes, Often and Very Often

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