Chapter 3. Method

3-1. Participants

The participants in the study were 1,234 10th grade students from 34 classes enrolled in a compulsory earth science course at 14 senior high schools in Taiwan. Their mean age was about 16. Thirty random-selected schools, 10% of total senior high school numbers in Taiwan, participated in this study. However, results from 14 among these 30 schools were taken into final analysis. The excluded results were due to the failure of completing all questionnaires or missing data in the questionnaires made by students. Final participating schools were distributed into four demographic areas, Northern, Central, Southern and Eastern Taiwan. Seven high schools from Northern Taiwan, two from Central Taiwan, three from Southern Taiwan and two from Eastern Taiwan were completed the whole survey. There were 34 classes of about 40 students each and a total of 677 males and 557 females (see table 1).

Each student in the sample had participated in pretest survey and posttest survey responded to the earth science classroom learning environment instrument (ESCLEI) and completed the earth science learning outcomes questionnaire (ESLOQ) in summer semester from September 2003 to February 2004.

Table 1. Description of the Sample

Major	N		No. of Classes	No. of Schools	No. of Teachers
Earth Science	1,234	Male 677 Female 557	34	14	17

3-2. Instruments

3-2-1. Earth Science Classroom Learning Environment Instrument

The earth science classroom learning environment instrument (ESCLEI) is designed to quantitatively measure the preference and fitness of science classroom LE with the focus on student-center and teacher-center, and to explore related issues in earth science teaching and learning (Lee and Chang, *in press*). The instrument consists of two subscales (student-centred and teacher-centred LEs) with both preferred and actual (or perceived) form pooled together.

Two advantages are worth pointing out in terms of the design of questionnaire.

- The design helps students to discriminate between their preferred and actual LE. Also, it does not cause any confusion when students answering these two form in the same time.
- It provides the information of progression/regression in person-LE fitness of students when they were taught during a semester.

There are fifteen items in each subscale and every item includes preferred and actual (or perceived) form, therefore, total of 60 items with a 1-5 Likert scale of Almost Never, Seldom, Sometimes, Often and Almost Always in the questionnaire (see Appendix-I).

Sample items from the ESCLEI include:

- Help to plan the teaching content and activities of the course.

1. My preferred, expected situation is……..
2. My actual experience was……

This is an example item of student-centred subscales, and each item includes two forms: a preferred form (odd number) and an actual form (even number). Appendix-III listed the detailed description of each item of the ESCLEI.

The properties of items include teaching method, teaching content and teaching evaluation in order to realize the earth science classroom LE (Lee and Chang, *in press*). Students were asked to rate to what extent they agreed that each item described their science classroom LE. Table 2 listed the number of items and the description of subscales and Table 3 listed the properties of items for each scale of the ESCLEI.

Each student respond to the ESCLEI had four kinds of scores: a preferred student-center score (PS), a preferred teacher-center score (PT), an actual student-center score (AS) and an actual teacher-center score (AT). Expect for the further statistically analyzed, in this study, using the class as the unit, the scores of ESCLEI have to plot data at X-Y scatter diagram for displaying the orientations of classroom LE (see figure 3). For collecting qualitative data in this study, the

instrument put in one question in the end of the questionnaire; the question is: what the most experience was you affect in the actual classroom? Please write down in brief (see appendix-I). The qualitative responses were used to support and verify quantitative data, and some further modifications to questionnaire items.

Table 2. Descriptive of scale and number of items for each scale of the ESCLEI

Scale name		*Description of scale*	*No. of items*
P	S	Extent to which students preferred the student-centred classroom learning environment, the principal part of the classroom learning environment consists with constructivist epistemology.	1, 3, 5, 19, 21, 23, 25, 27, 29, 33, 43, 47, 49, 51, 53
	T	Extent to which students preferred the teacher-centred classroom learning environment, the principal part of the classroom learning environment consists with traditionally pedagogy.	7, 9, 11, 13, 15, 17, 31, 35, 37, 39, 41, 45, 55, 57, 59
A	S	Extent to which students perceived the student-centred classroom learning environment, the principal part of the classroom learning environment consists with constructivist epistemology.	2, 4, 6, 20, 22, 24, 26, 28, 30, 34, 44, 48, 50, 52, 54
	T	Extent to which students perceived the teacher-centred classroom learning environment, the principal part of the classroom learning environment consists with traditionally pedagogy.	8, 10, 12, 14, 16, 18, 32, 36, 38, 40, 42, 46, 56, 58, 60

P: preferred, A: actual, S: student-centred, T: teacher-centred.

Table 3. The properties of items for each scale of the ESCLEI

Scale		Student-center			Teacher-center		
Property / Items		Method	Content	Evaluation	Method	Content	Evaluation
Prefer	Actual						
1	2	∗	⊙				
3	4	⊙	∗				
5	6	⊙					
7	8					∗	⊙
9	10				∗	⊙	
11	12				∗	⊙	
13	14				∗	⊙	
15	16				⊙	∗	
17	18				⊙		
19	20		∗	⊙			
21	22	∗	⊙				
23	24	∗	⊙				
25	26	⊙					
27	28		⊙				
29	30		⊙	∗			
31	32				⊙		
33	34	∗		⊙			
35	36				⊙		
37	38				⊙		
39	40					⊙	
41	42					⊙	∗
43	44	⊙					
45	46				∗		⊙
47	48	⊙					
49	50	⊙					
51	52	∗		⊙			
53	54	∗		⊙			
55	56				⊙		
57	58				∗		⊙
59	60				∗		⊙

⊙ ：Major　　∗ ：Minor

The instrument was pilot tested using 167 tenth grade students enrolled in four earth science class at two senior high schools in April 2003 of Taiwan (Lee and Chang, *in press*), and six students of them were interviewed regarding their interpretation and understanding of items. The instrument also reviewed by a panel of specialists, including three science education professors and three high school teachers, established the content validity of ESCLEI. Suggested modifications obtained from the reviews and pilot study were used to produce the present form of ESCLEI in this study.

The Cronbach's alpha of the ESCLEI was estimated to be around be 0.88 in pilot study and was calculated at 0.92 (in pre-test) and 0.93 (in post-test) with the present sample in this study. The ESCLEI has four subscales: the classroom LE preferred to student-centred form (PS), classroom LE preferred to teacher-centred form (PT), actual classroom LE was in student-centred form (AS) and actual classroom LE was in teacher-centred form (AT). The Cronbach's alpha for each subscale of the ESCLEI were 0.85, 0.73, 0.80 and 0.69 respectively in pilot study and was estimated at 0.87 (0.89), 0.83 (0.86), 0.81 (0.85) and 0.78 (0.83) with present sample in the pre-test (post-test) study. Table 4 list the Cronbach's alpha reliability values of the ESCLEI. Principal components factor analysis of each subscales (i.e., PS, PT, AS and AT) confirmed the construct validity of the instrument. Nearly the

items in each of the subscales had loading on one scale (i.e., student-center or teacher-center) both in pilot study and present study.

The mean correlation of a scale with other scales was used as a convenient index of discriminant validity. It was varied between 0.28 to 0.36 for the individual of the unit of analysis in pilot study (Lee and Chang, *in press*) and was estimated between 0.31 to 0.51 for the individual of the unit of analysis in present study (see table 4).

An analysis of variance (ANOVA) was used to determine the ability of each ESCLEI subscale to differentiate between the perceptions of students in different classes. The eta^2 statistic was calculated to provide an estimate of the strength of association between class membership and the dependent variable (ESCLEI subscale). Table 4 presents the ANOVA results (η^2) for pre- and post-test. Each subscale differentiated significantly between classes ($p < 0.001$) in both pre- and post-test. The amount of variance in scores accounted for by class membership (i.e. η^2) ranged from 0.09 to 0.15 in pre-test and from 0.08 to 0.14 in post-test for different ESCLEI subscales. Consequently, the instrument was found to be a reliable and valid measure for assessing the orientations of earth science classroom LE.

Table 4. Cronbach's alpha reliability, discriminant validity (mean correlation with other scales) and ability to differentiate between classrooms for the ESCLEI

Scale		*Cronbach's alpha reliability*						*ANOVA results (η^2)*		*Mean correlation with other scales*
		Pre-	*Post-*	*Pre-*	*Post-*	*Pre-*	*Post-*	*Pre-*	*Post-*	
P	S	0.87	0.89	0.90	0.92	0.92	0.93	0.09**	0.08**	0.48
	T	0.83	0.86					0.09**	0.08**	0.51
A	S	0.81	0.85	0.85	0.86			0.15**	0.14**	0.31
	T	0.78	0.83					0.09**	0.11**	0.51

**$p < 0.001$. P: preferred, A: actual, S: student-center, T: teacher-center. N = 1,234

3-2-2. Assessments of Earth Science Learning Outcomes

To assess students' earth science learning outcomes, a questionnaire include attitudes toward the earth science inventory (ATESI) (Chang 2003, Chang and Mao 1999) and the earth science achievement test was administered, named the earth science learning outcomes questionnaire (ESLOQ). The ESLOQ has two sections with a total 60 items; first section is the ATESI with 30 items, second section is the science achievement test composed of another 30 items (see appendix-II).

The attitudes toward earth science inventory (ATESI) consists of 30 items with bipolar disagree/agree statements on a 1-5 Likert scale intended to investigate students' attitudes toward earth science with three subscales assessing attitudes toward the earth science subject, attitudes toward learning of earth science, and attitudes toward involvement in earth science activities. Internal reliability was shown to be adequate; the Cronbach's alpha was estimated to be around 0.90 in previous studies and was calculated at 0.93 (0.93) with the present sample in the pre-test (post-test) study (see table 5). The Cronbach's alpha of the ATESI subscales for attitudes toward the earth science subject, learning earth science and involvement in earth science activities were 0.82, 0.85 and 0.78 respectively in previous studies and was estimated at 0.85 (0.86), 0.87 (0.86) and 0.81 (0.78) with present sample in

the pre-test (post-test) study (see table 5). The inventory's validity and selected examples of the ATESI can also be found in Mao and Chang (1998).

The earth science achievement test is composed of 30 single-choice question, which is designed to measure students' earth science achievement. It was referred to a science examination instrument which had used to investigate by the College Entrance Examination Center (CEEC) in Taiwan. The science examination instrument was developed and modified from the CEEC in 2002 and the intention of the instrument was to investigate on students' responds, which was included: the design of items, the difficulty of items and the declaration of items. Consequently, the content validity and the internal reliability of the instrument were shown to be adequate. Appendix-IV listed the passing rate and discrimination of each item of the ESLOQ-achievement.

The items of the earth science achievement test in this study were sifted the questions which were mainly aimed at earth science and had quite discriminant validity from the science examination instrument by the CEEC, and a total of 30 items was selected. A panel of specialists, including a university professor and three high school teachers, established the content validity of the earth science test. These specialists checked the declaration and the correctly answered of the items again. The reliability coefficient was estimated at 0.78 (0.83) for the present sample in the

pre-test (post-test) study, using the Kuder-Richardson Formula 20 (KR-20) (see table 5).

Table 5. The internal reliability for the ESLOQ.

ATESI (Cronbach's alpha)								Achievement (KR-20)	
Subject		Learning		Activities		Total		Pretest	Posttest
Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest		
0.85	0.86	0.87	0.86	0.81	0.78	0.93	0.93	0.78	0.83

3-3. Design and Procedure

A pre-test post-test survey design involving 1,234 students from 34 classes at 14 schools was adopted. The participants were tested and surveyed before and after the semester to both instruments, i.e., ESCLEI and ESLOQ. The pre-test survey was completed in September 2003, and the post-test survey was completed in February 2004. Figure 2 reported the summary of research design and procedure. The participants had to complete the ESCLEI in 25 minutes in a lesson first and completed the ESLOQ in 40 minutes in another lesson both in pre-test survey and post-test survey. In this study, we used the class as the unit to analysis.

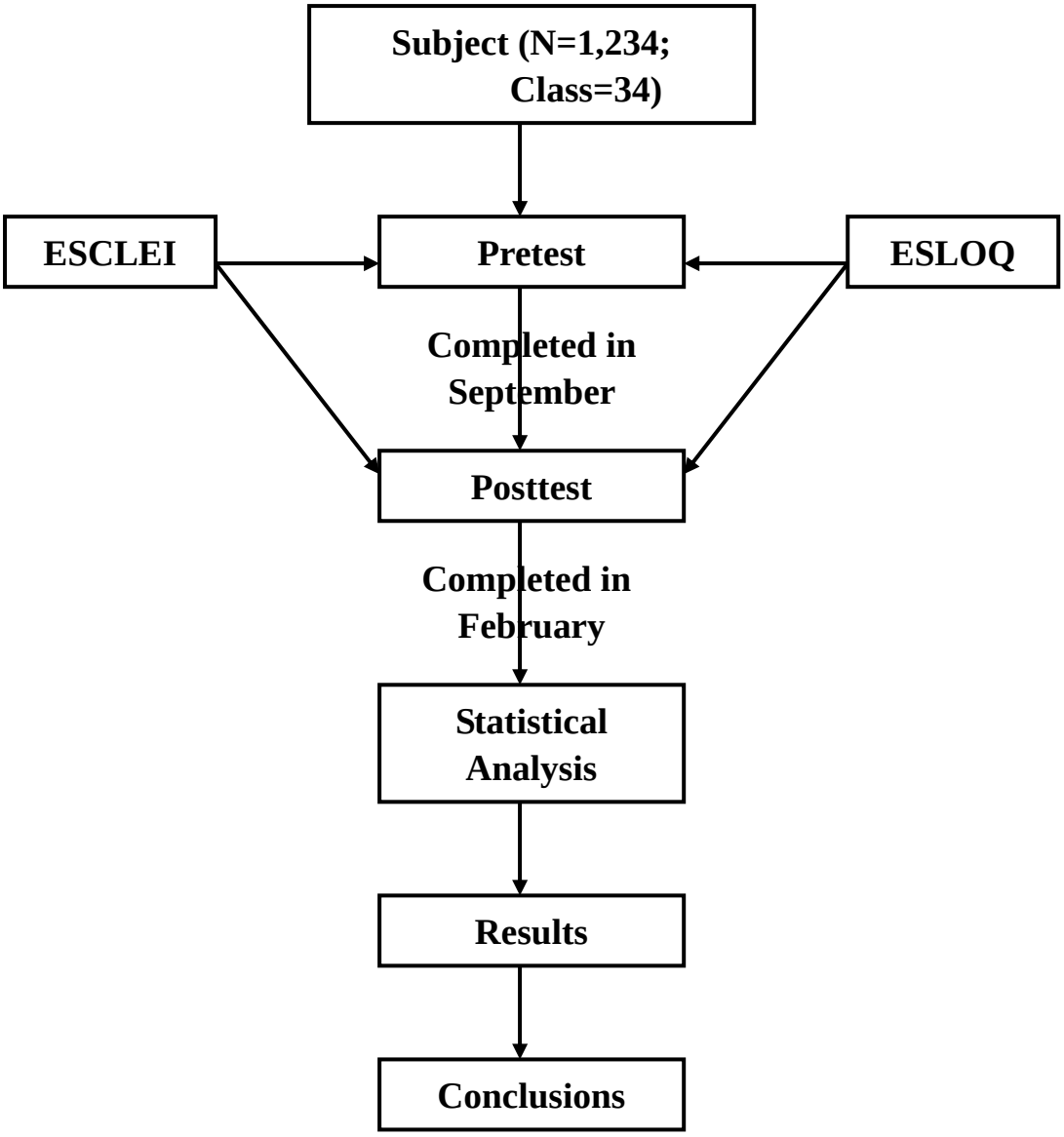

Figure 2. Summary of Research Design and Procedure.

3-4. Data Analysis

To understand what science classroom LEs would be preferred and perceived (actual) of the students, the mean scores of classes on subscales (PS, PT, AS and AT) in ESCLEI was plotted in X-Y scatter diagram (Lee and Chang, *in press*) which were conducted using Microsoft® Office Excel. The X-Y scatter diagram has preferred form and actual form. The preferred (actual) form would be plotting PT (AT) mean score against a Y-axis and plotting PS (AS) mean score against an X-axis. The 1-5 Likert scale was adopted by the ESCLEI, so the highest score would be 5 point and the lowest score would be 1 point. The X-Y scatter diagram has 1 to 5 point both in a Y-axis and an X-axis, and a Y-axis would be crossed with an X-axis at 3 point (see figure 3), so the scatter diagram would be demarcated to four quadrants.

In figure 3, the first quadrant represented that students preferred (or perceived) both the student-centred and teacher-centred classroom LE (ST), the second quadrant represented that students preferred (or perceived) the teacher-centred classroom LE (T), the third quadrant represented that students preferred (or perceived) both not the student-centred and teacher-centred classroom LE (NST), and the forth quadrant represented that students preferred (or perceived) the student-centred classroom LE (S).

To further understand related issues in earth science teaching and learning of classroom LE, in addition to descriptive statistical analysis, the *T* tests were necessary. *T* tests for paired samples, using class as the unit of analysis, were used to investigate whether differences in subscale score (i.e., student-center and teacher-center) both in pre-test and post-test survey between preferred and actual classroom LE were statistically significant. The level of confidence was set at a 0.05 level of significance.

A person-LE fitness (PEF) was computed for each student by finding the difference between the scores on the ESCLEI when students described the "preferred classroom LE" and when they described the "actual classroom LE" both in student-center and teacher-center for their classroom. PEF scores were computed by subtracting actual ESCLEI scores from preferred ESCLEI scores both in student-centred and teacher-centred form, this would indicate variance between what a student would preferred and what the student feels exists in their classroom. So each student has two PEF scores, i.e. a PEF score in student-center (PEFS) and a PEF score in teacher-center (PEFT). The following will exemplify how to arrive at this score. Whenever the ESCLEI is administered:

PS Score minus **AS Score = Person-LE Fitness in student-center (PEFS)**

PT Score minus **AT Score = Person-LE Fitness in teacher-center (PEFT)**

In order to have a better look into associations between student attitudes, student achievements, and the progression/regression in PEF of students, the analysis of Pearson product-moment correlation was conducted. The analysis using the class as the unit, were used to investigate whether relations were statistically significant between the progression/regression in PEFS, PEFT and the ESLOQ subscales (student attitudes and achievements) among pre- and post-test survey. The level of confidence was also set at a 0.05 level of significance. When the pre-test PEF score is subtracted from post-test PEF scores, another sum, called the classroom climate vector (CV) is determined (Diamantes 2002). In this study, each class has two CV scores, i.e. a CV score in student-center (CVS) and a CV score in teacher-center (CVT). The following will exemplify how to arrive at this score:

Post-test PEFS Score minus **Pre-test PEFS Score = CV score in student-center (CVS)**

Post-test PEFT Score minus **Pre-test PEFT Score = CV score in teacher-center (CVT)**

To meet contemporary calls for improvement in the interpretation and reporting of quantitative research in education (e.g., APA 2001, Rennie 1998, and Thompson 1996 and 2002), this study reports practical significance (effect magnitudes) along

[1] American Psychological Association, APA.

with each statistical significance test. The effect size index d was used since it is more appropriate for the analysis of *T* test (Cohen 1988). According to Cohen's rough characterization (1988, pp. 24-26), d = 0.2 is deemed as a small effect size, d = 0.5 a medium effect size, and d = 0.8 as the large effect size. The assumptions of *T* tests were first checked to ensure that they were met in the analysis of covariance for the present study (see Glass and Hopkins 1996, pp. 290-296). Tests of the assumptions for inferential statistical analyses were conducted using statistical package for social sciences for windows 11.0 (SPSS version 11.0 made by SPSS Inc., Chicago, IL). Also, the effect size for the analysis of simple correlation (*r*), according to Cohen's rough characterization (1988, pp. 78-83), *r* = 0.1 is deemed as a small effect size, *r* = 0.3 a medium effect size, and *r* = 0.5 as the large effect size.