The Effect of Learning Environments on Student Attitude and Cognitive Achievement in Physical Chemistry Laboratory Classrooms

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Abstract: The purposes of this study were to analyse the learning environment, teacher-student interactions and educational outcomes in physical chemistry laboratory classrooms in Thailand. The Actual Forms of the Chemistry Laboratory Environment Inventory (CLEI) which was the modified version of the Science Laboratory Environment Inventory (SLEI), and the Questionnaire on Teacher Interaction (QTI) were used with 100 physical chemistry students in four Rajabhat Universities in Thailand. Students' learning achievement was examined using a cognitive test and the Attitude Scale. The students' attitudes to their physical chemistry laboratory class were assessed with a ten-item scale based on the Test Of Science Related Attitudes (TOSRA). Before the questionnaires were used with the 100 student sample, the reliability and validity of the CLEI, QTI and Attitude Scale were confirmed with 198 physical chemistry students in nine classes in seven Rajabhat Universities. This study is distinctive in that it examines a combination of the CLEI, the QTI, attitudinal outcomes and cognitive outcomes with students studying a physical chemistry laboratory subject in tertiary science classrooms in Thailand. The study found that there were differences between the students' actual learning environments at the beginning of the semester and what they perceived to be actually present at the end of the semester. Associations were also found between students' perceptions of the actual classroom environment and student attitude and cognitive achievement. As the results, students improved on their attitude and cognitive achievement. Therefore, the 35-item CLEI and 48-item QTI that are incorporated in the same study involving laboratory physical chemistry environment are useful for teaching and learning. Moreover, the reliability and validity data on the CLEI and the QTI led teachers and researchers to use these questionnaires with confidence in physical chemistry laboratories and classrooms in Thailand at the tertiary level.
Keywords: Actual Form of the Chemistry Laboratory Environment Inventory, Actual Form of the Questionnaire on Teacher Interaction, Students' perceptions, Student attitude and cognitive achievement.

Introduction

For some time, the Schools Council of the Education and Training in Thailand has been concerned with issues about physical chemistry laboratory instruction and student perceptions of physical chemistry laboratory learning environments (The World Bank Group, 1999; Nantiya, 1999). Many researchers have said that the learning environment in the classroom is important in enhancing student learning. Wallin (2003) said that effective teaching might be summarized as having three dimensions: the classroom itself, the teaching style, and the learning environment. Wallin continued to say that the learning environment can lead to effective classroom learning within a supportive atmosphere, where students work in both small and large groups, in individualized learning activities, as well as in cooperative learning environments. It means that students are given ample time and opportunity to master skills, and students assume a high degree of responsibility for their learning through participation, by becoming involved in setting their own learning goals, and helping to monitor their own progress. The nature of teacher-student interactions and learning environments can contribute to the effective classroom learnings, for as Banyat (1998) said, both the psychological environment and the physical environment can enhance the learning in classrooms.

Even though the field of classroom learning environment provides ideas and techniques that could be very valuable in assisting teachers to become more reflective and to improve their practice, little progress has been made in incorporating learning environment ideas into physical chemistry laboratory classes (Fraser, 1989a). Also, despite the current availability of convenient questionnaires to measure classroom environment, little has been reported on attempts. to improve the learning environment of university classes in Thailand. Again, even though the study of learning environment has been undertaken in other countries for a long time, it is a new subject in Thailand, and especially the learning environment of a physical chemistry laboratory class at university level.

Background to Instruments Used in This Study

Science Laboratory Environment Inventory (SLEI)

The Science Laboratory Environment Inventory (SLEI) was specifically developed to assess the environment of science laboratory classes at secondary or higher education levels. It was constructed to elicit student perceptions of their science laboratory learning environment to answer the following questions; 1) what effect does the laboratory activities have upon student learning?; and 2) Should other outcomes be investigated by a science laboratory learning environment questionnaire? (Fraser, Giddings, & McRobbie, 1995; Fraser & McRobbie, 1995). The 35-item version of the SLEI spreads over five scales, and the five alternative responses for each item are Almost Never, Seldom, Sometimes, Often and Very Often (Waldrip, 1994). The first version of the SLEI was developed in a Class Form, which assessed the individual student's perception of the class as a whole (Lightburn, 2002). The meaning of each of the five scales in the SLEI is shown in Table 1. Table 1 contains a scale description and sample item for each scale. The reliability of the scales in this 35-item version ranged from 0.62 to 0.82 (Waldrip, 1994). The SLEI was further developed to include a Personal Form, which assesses a student's perception of an individual's role within the class. As such, Fraser, Giddings, and McRobbie (1995) constructed the Personal Form of SLEI, which asked students for their personal perceptions of the laboratory environment. The example items in Table 1 are from the Personal Form in that the items are in the Actual Form. The actual form suggests to students rating what their class is actually like.

Table 1. *Descriptive Information for Each Scale of the SLEI*

Scale name	Moos category	Description	Sample item
Student Cohesiveness	R	Extent to which students know, help and are supportive of one another.	I get along well student in this laboratory class. (+)
Open-Endedness	P	Extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation .	In my laboratory sessions, the teacher decides the best way for me to carry out the laboratory experiments. (-)
Integration	P	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	I use the theory from my regular science class sessions during laboratory activities. (+)
Rule Clarity	S	Extent to which behaviour in the laboratory is guided by formal rules.	There is a recognised way for me to do things safely in this laboratory. (+)
Material Environment	S	Extent to which the laboratory equipment and materials are adequate.	I find that the laboratory is crowded when I am doing experiments. (-)

R: Relationship dimension; P: Personal Development dimension, S: System Maintenance and System Change dimension.
Items designated (+) are scored 1,2,3,4 and 5 respectively for the responses Almost Never, Seldom, Sometimes, Often and Very Often. Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3.

(Source: adapted from Giddings & Fraser, 1989).

The SLEI was field tested and validated simultaneously with many samples in six different countries (Fraser & McRobbie, 1995; Fisher, Henderson, & Fraser, 1997; Wong & Fraser, 1995). It is desirable for science teachers to make use of the SLEI to monitor students' views of their laboratory classes, investigate the impact that different laboratory environments have on student outcomes, and provide a basis for guiding systematic attempts to improve these learning environments. Fraser, Giddings, and McRobbie (1992) consistently noted that in order to stimulate fruitful discussion and guide improvement attempts as a part of school-based professional development initiatives, the SLEI is easily administered and scored, providing an excellent foundation for attempts to improve the laboratory environments.

A modified version of the SLEI named the Chemistry Laboratory Environment Inventory (CLEI) (Wong, Young, & Fraser, 1997) was used in this study to assess students' perceptions of learning environments in physical chemistry laboratory classes. In this version of the SLEI, the word 'science' was change to 'physical chemistry'. For example, a sample item in the SLEI scale such as 'I get on well with students in this laboratory class' will be changed in the CLEI scale to 'I get on well with students in this physical chemistry laboratory class'. Fraser, Giddings, and McRobbie (1995) were the designers for this modification. Although the CLEI was modified from the SLEI, most scales of the CLEI were found to be reliable as shown in Table 2.

Table 2. *Internal Consistency Reliability (Cronbach Alpha Coefficient) for CLEI and Original SLEI Scales for Two Units of Analysis.*

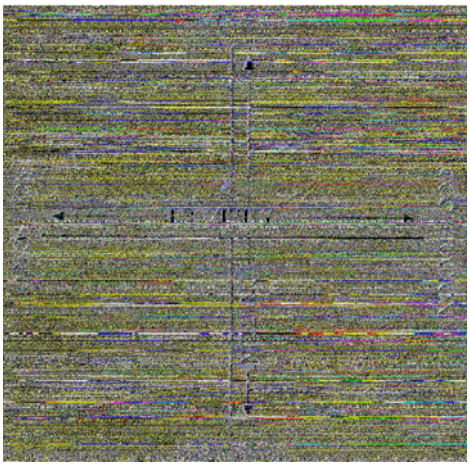
Scale Name	No. of Items	Unit of Analysis	Alpha Reliability	
			CLEI[a]	SLEI[b]
Student Cohesiveness	7	Student	0.68	0.78
		Class	0.83	0.80
Open-Endedness	6	Student	0.41	0.71
		Class	0.54	0.80
Integration	7	Student	0.69	0.86
		Class	0.87	0.91
Rule Clarity	6	Student	0.63	0.74
		Class	0.84	0.76
Material Environment	7	Student	0.72	0.76
		Class	0.82	0.74

[a]For the CLEI, the sample consisted of 1,592 upper secondary chemistry students in 56 classes in Singapore. [b]For the SLEI, the sample consisted of 516 senior high school students in 56 chemistry classes in Australia.
(Source: Wong, Young, & Fraser, 1997)

Questionnaire on Teacher Interaction (QTI)

The Questionnaire on Teacher Interaction (QTI), which draws upon a theoretical model of proximity (cooperation-opposition) and influence (dominance-submission), was developed to assess student perceptions of eight behaviour aspects. Wubbels, Créton, & Hooymayers (1985) developed the eight-dimensional model of interpersonal behaviour and plotted on a two-dimensional coordinate system as shown in Figure 1. The two-dimensional coordinate system of interpersonal behaviours was labeled as "Affection-Hostility" and "Dominance-Submission" (Leary, 1957). Wubbels, Brekelmans, and Hermans (1987) adapted this version of the Leary model in a general framework of eight dimensions, but some labels were redefined and modified. This model referred to two primary dimensions: an Influence

dimension (Dominance, D - Submission, S) and a Proximity dimension (Cooperation, C - Opposition, O). The Influence dimension was described as measuring dominance and submissiveness in a relationship. The Proximity dimension was described as measuring the degree of cooperative or oppositional behaviour between those communications. Figure 1



shows the two-dimensional model as adapted by Wubbels and Levy (1993).

Figure 1: *The two-dimensional coordinate system of the Leary model*.
(Source: Wubbels, Créton, Levy, & Hooymayers, 1993, p. 15)

From Figure 1, the two primary dimensions can be divided into eight sections in a coordinate system as shown in Figure 2.

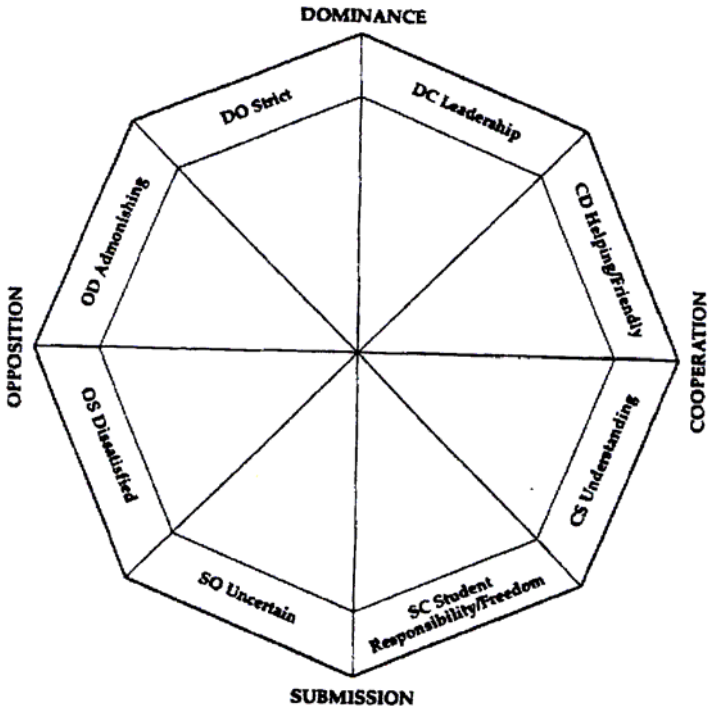


Figure 2: *The model for interpersonal teacher behaviour.*
(Source: Wubbels, 1993)

Each sector in Figure 2 describes the different facets of teacher behaviour. Each instance of the teacher behaviour can be placed in eight sectors when this model is used. DC, CD, CS, SC, SO, OS, OD and DO labels in the sections of the model for interpersonal teacher behaviour are defined in terms of typical behaviours within a category. For example, the DC label is the Dominant-Cooperative sector, but more dominant than cooperative for the teacher perceived by students. This model is called the circumplex model because adjacent sectors in this model represent the similar interpersonal behaviours whilst opposite sectors represent the opposite behaviours. The QTI was first developed in The Netherlands (Wubbels, Créton, & Hooymayers, 1985). The original form was written in Dutch, but it has been translated into English and used both in the USA (Wubbels & Levy, 1989, 1991) and Australia (Fisher, Fraser, Wubbels, & Brekelmans, 1993). The QTI was then developed into a 48-item English version in which the eight scales consist of six items each. This version has been used increasingly in Australia (Fisher, Fraser, & Rickards, 1997; Fisher, Fraser, & Wubbels, 1993; Fisher, Henderson, & Fraser, 1995; Wubbels, 1993). This 48-item version formed the basis of the Thai version used for my study.

The eight sectors shown in Figure 2 are explained in Table 3 that characterises interpersonal behaviour in each sector by providing a scale description, along with a sample item for each scale. That is the Actual Form of the QTI which examines the student's perception of the actual teacher-student interpersonal behaviour. In all versions of the QTI, responses to the items are given on a five-point Likert scale, scoring from 0 (Almost Never) to Very Often (4) on the questionnaire.

Table 3 *Description of Scales and Sample Items for Each Scale of the QTI*

Dimension or scale name	Description of scale (the extent to which the teacher..)	Sample item
Leadership	…leads, organises, gives orders, determines procedure and structures the classroom situation.	This teacher talks enthusiastically about his/her subject
Helping/Friendly	…Show interest, behaves in a friendly or considerate manner and inspires confidence and trust.	This teacher helps us with our work.
Understanding	…listens with interest, empathises, shows confidence and understanding and is open with students.	This teacher trusts us.
Student Responsibility & Freedom	…gives opportunity for independent work, gives freedom and responsibility to students.	We can decide some things in this teachers class.
Uncertain	…behaves in an uncertain manner and keeps a low profile.	This teacher seems uncertain.
Dissatisfied	…expresses dissatisfaction, looks unhappy, criticises and waits for silence.	This teacher thinks that we cheat.
Admonishing	…gets angry, express irritation and angry, forbids & punishes.	This teacher gets angry unexpectedly.
Strict	…checks, maintains silence and strictly enforces the rules.	This teacher is strict.

Items are scored 0, 1, 2, 3, and 4, respectively, for the responses Almost Never, Seldom, Sometimes, Often, Very Often. (Source: adapted from Wubbels, 1993)

The QTI has been confirmed as a valid and reliable questionnaire in various countries, such as The Netherlands, the USA and Australia. As such the 48-item QTI used with an Australian study (Wubbels, 1993) involved 792 students and 46 teachers and the reliability

for both the students' and teachers' responses ranged from 0.68 to 0.85, showing a satisfactory level of reliability (Cresswell & Fisher, 1996). When a 64-item version of the QTI was used in the USA (Wubbels & Levy, 1993) with 1,606 students and 66 teachers, the Cronbach alpha coefficient was found to range from 0.76 to 0.84 for the student responses and from 0.74 to 0.84 for the teacher responses (Rickards, Fisher, & Fraser, 1996).

Methodology

Objectives of the study

The four objectives of this study were to (1) provide further validation information about the CLEI and the QTI questionnaires in terms of reliability for use in the physical chemistry laboratory classrooms in Thailand; (2) investigate students' perceptions of their physical chemistry laboratory classes and their teacher-student interactions; (3) investigate attitudes students have towards their subject of physical chemistry laboratory; and (4) investigate associations between the students' perceptions of their learning environments in the physical chemistry laboratory, and attitudinal, cognitive outcomes, and of their teacher's interpersonal behaviour.

Translation into Thai and back translation

Initially, the English versions of the CLEI and QTI were translated to Thai versions by Thai teachers from Nakhon Sawan Rajabhat University. Then, an independent back translation of the Thai versions to the English versions was done by an individual who was not involved in the original translation. This was to ensure that items retain their original meanings.

The students' attitudes to their physical chemistry laboratory class were assessed with a ten-item scale based on the Test Of Science Related Attitudes (TOSRA) (Fraser, 1981; Fisher, Henderson, & Fraser, 1995). The English version of the Attitude Scale was translated into a Thai version using the same translation procedure as mentioned above. Moreover, the word "science" in those scales was replaced with "physical chemistry laboratory".

The external examination was included in order to investigate students' cognitive achievement outcome. Thai versions of these tests were also sent to five experts for comment, then taken to students for trial, and finally modiFied to ensure greater validity and reliability.

Data collection and analysis

Data were collected on three occasions between weeks 2 and 15 of the same semester. That is: during early, mid and end semecter. The Actual Form of the CLEI, Actual Form of the QTI, the Attitude Scale, and cognitive test were administered with students in early semester or during week 2 of the study.

When the questionnaires and two tests (attitude test and external examination) were returned to the researcher, they were rearranged and checked by the researcher. Responses to the questionnaires and the two tests were manually scored by the researcher. Data from the CLEI and QTI, which were missing or had invalid scores by any student, were treated as missing vaLues by the SPSS program.

Simple and multiple correlation analyses are used to determine associations between students' perceptions of learning environment and students' attitudinal and cognitive outcomes. The simple correlation (*r*) describes a bivariate association between two variables

whereas the multiple correlation (*R*) indicates the association between two variables when all other variables are controlled (Henderson, Fisher, & Fraser, 1995).

Results and Discussion

Validation of CLEI and QTI

Tables 4 shows the reliability and validity figures for the CLEI when used with 198 science students at Thai universities. Results from the study indicated that the CLEI is a valid and reliable instrument for the assessment of students' perceptions in physical chemistry laboratory classrooms in Thailand. Table 5 also presents the reliability and validity figures for the QTI indicating that the QTI is a valid and reliable instrument for use in physical chemistry laboratory classrooms in Thailand.

Table 4. *Internal Consistency (Cronbach Alpha Coefficient) and Ability to Differentiate Between Classrooms for the CLEI.*

Scale	No of items	Unit of Analysis	Alpha Reliability Actual	Alpha Reliability Preferred	Mean Correlation with Other Scales	Anova Results (Eta^2) Actual
Student Cohesiveness	7	Individual	0.62	0.61	0.26	0.09*
		Class mean	0.75	0.70	0.55	
Open-Endedness	7	Individual	0.62	0.61	0.12	0.07
		Class mean	0.63	0.63	0.59	
Integration	7	Individual	0.71	0.67	0.34	0.10**
		Class mean	0.88	0.90	0.47	
Rule Clarity	7	Individual	0.61	0.60	0.31	0.08*
		Class mean	0.72	0.62	0.50	
Material Environment	7	Individual	0.71	0.61	0.35	0.19***
		Class mean	0.88	0.77	0.63	

*p<0.05, **p<0.01, ***p<0.001
The sample consisted of 198 Thai science students in nine classrooms in seven Rajabhat Universities.

Table 5 *Internal Consistency (Cronbach Alpha Coefficient) and Ability to Differentiate Between Classrooms for the QTI.*

Scale	Unit of Analysis	Alpha Reliability Actual	Alpha Reliability Ideal	Anova Results (Eta^2) Actual
DC Leadership	Individual	0.78	0.74	0.16***
	Class mean	0.94	0.91	
CD Helping/ Friendly	Individual	0.77	0.72	0.13***
	Class mean	0.89	0.85	
CS Understanding	Individual	0.73	0.78	0.08*
	Class mean	0.82	0.89	
SC Student Resp/Freedom	Individual	0.60	0.61	0.05
	Class mean	0.68	0.65	
SO Uncertain	Individual	0.77	0.71	0.11**
	Class mean	0.83	0.87	
OS Dissatisfied	Individual	0.72	0.71	0.14***
	Class mean	0.82	0.72	
OD Admonishing	Individual	0.75	0.67	0.18***
	Class mean	0.89	0.84	
DO Strict	Individual	0.67	0.63	0.07
	Class mean	0.81	0.73	

*p<0.05, **p<0.01, ***p<0.001
The sample consisted of 198 Thai science students in nine classrooms in seven Rajabhat Universities.

For these results, the alpha reliability of CLEI ranged from 0.61 to 0.71 for the Actual Form when the individual student was used as a unit of analysis. When the class mean was used as a unit of analysis, the alpha reliability of CLEI ranged from 0.63 to 0.88 for the Actual Form. These results are comparable with previous research with the CLEI. For example, Wong, Young, and Fraser (1997) reported that the reliabilities of the CLEI ranged from 0.41 to 0.72 when the individual student was used as the unit of analysis, and from 0.54 to 0.87 when the class mean was used as the unit of analysis; and Quek, Wong, and Fraser (2001) revealed that the reliabilities of the CLEI ranged from 0.53 to 0.76 for the Actual Form when the individual student was used as the unit of analysis. For the mean correlation of each scale with the other scales used as a mean of measuring the discriminant validity of the CLEI, it was found that scores of the mean correlations ranged from 0.12 to 0.35 when the individual student was used as a unit of analysis, and from 0.47 to 0.63 when the class mean was used as a unit of analysis. The discriminant validity figures of all the scales in the Actual Form of the CLEI in this study were higher than those reported for the Actual Form of the CLEI in a previous study by Quek, Wong, and Fraser (2001) with Singaporean students (Actual Form ranged from 0.11 to 0.24). In addition, four CLEI scales, with one exception for the Open-Endedness scale, significantly differentiated between classes since the eta^2 statistic ranged from 0.08 to 0.19. The results are similar to the previous study of Quek, Wong, and Fraser (2001) using the CLEI with Singaporean students where the eta^2 value ranged from 0.06 to 0.21.

When the individual student was used as a unit of analysis, the alpha reliability of QTI ranged from 0.60 to 0.78 for the Actual Form. When the class mean was used as a unit of analysis, the alpha reliability of QTI ranged from 0.68 to 0.94 for the Actual Form. The reliability figures are quite consistent with previous study. For example, Fisher and Rickards (1996) reported that the reliability figures ranged from 0.62 to 0.88 when the individual student was used as the unit of analysis, and from 0.60 to 0.96 when the class mean was used as the unit of analysis. The six QTI scales significantly differentiated between classes because the eta^2 statistic ranged from 0.08 to 0.18. The results support the validity seen in previous study when the 48-item version of the QTI was used. For example, Wubbels and Levy (1991) reported that eta^2 ranged from 0.36 to 0.59. As well, High correlation between Helping/Friendly and the Leadership, and Understanding scales were found. However, the Dissatisfied scale was low correlation with the Helping/Friendly scale. These indicated that the inter-scale correlation of the QTI presents validity in this study as shown in Table 6. These results confirm the circumplex nature of the QTI model supporting its validity for use.

Table 6. *Figures of Inter-Scale Correlation of Actual QTI Scales for Two Units of Analysis.*

Scale	Unit of Analysis	DC	CD	CS	SC	SO	OS	OD	DO
DC Leadership	Student	1.00	0.63	0.72	0.16	-0.36	-0.30	-0.46	0.04
	Class mean	1.00	0.79	0.89	-0.19	-0.68	-0.68	-0.82	0.29
CD Helping/	Student		1.00	0.63	0.14	-0.34	-0.25	-0.40	0.12
Friendly	Class mean		1.00	0.94	-0.28	-0.70	-0.86	-0.70	0.57
CS Understanding	Student			1.00	0.22	-0.28	-0.26	-0.36	0.04
	Class mean			1.00	-0.15	-0.62	-0.80	-0.73	0.39
SC Student Resp/	Student				1.00	0.31	0.29	0.25	-0.01
Freedom	Class mean				1.00	0.54	0.37	0.61	-0.74
SO Uncertain	Student					1.00	0.62	0.69	0.07
	Class mean					1.00	0.79	0.91	-0.53
OS Dissatisfied	Student						1.00	0.67	0.33

	Class mean	1.00	0.80	-0.49
OD Admonishing	Student		1.00	0.19
	Class mean		1.00	-0.50
DO Strict	Student			1.00
	Class mean			1.00

The sample consisted of 198 Thai science students in nine classrooms in seven Rajabhat Universities.

Students' perceptions of their physical chemistry laboratory classes and their teacher-student interactions

The results in Table 7 and Figure 3 allow a comparison of students' perceptions of their actual learning environments at the end of the semester with what they actually perceived at the beginning of the semester. It was note worthy that the students perceived high levels of cohesiveness with one another but little open-ended opportunities in their work. The high level of student cohesiveness in the physical chemistry laboratory suggests that the students were likely to do their laboratory work in groups and support and help each other. Possibly, the students were made to study many topics in physical chemistry in one semester, therefore, they though that it would be preferable to share the laboratory work load. Students perceived a low level of open-endedness, indicating that they had few opportunities to make their own decisions about their laboratory experiments. Colburn (1997) and McComas (1997) suggested that if students could decide on the problems and investigations in laboratory activities on their own, they would perceive a more open-ended environment.

Table 7. *Pre Actual and Post Actual Means and Differences on Scales of the CLEI.*

	Pre Actual	Post Actual	Difference (Post-Pre actual)	*t* test
Student Cohesiveness	27.84	28.87	1.03	2.11*
Open-Endedness	21.26	22.39	1.13	2.37*
Integration	26.54	27.53	0.99	1.71
Rule Clarity	26.04	26.79	0.75	1.57
Material Environment	24.79	24.09	-0.70	1.17

*$p<0.05$, n = 100

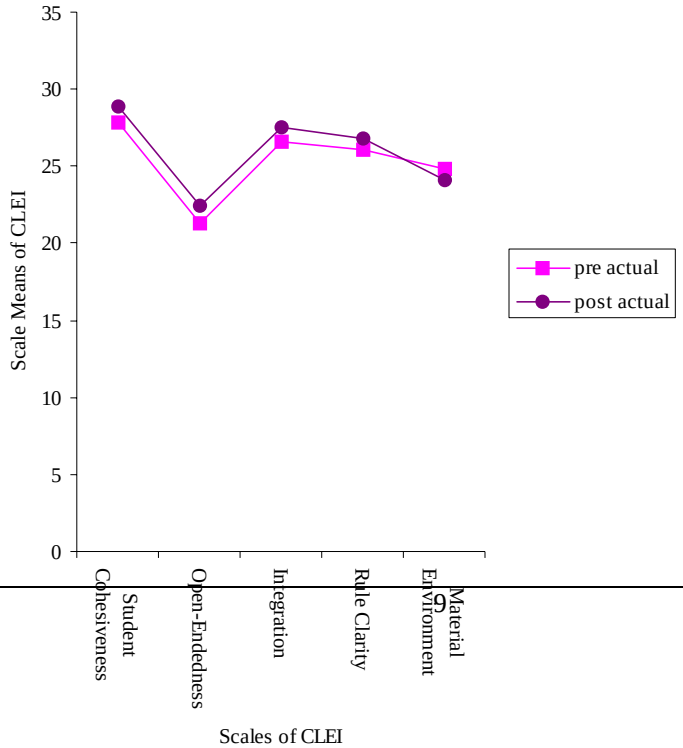


Figure 3: *Scale means for pre and post actual forms of the CLEI.*

The results shown in Table 8 and Figure 4 indicate that the students observed that their teachers at the end of the semester had levels of admonishing behaviour lower than they observed at the beginning of the semester. It suggested that Thai physical chemistry teachers are able to control their tempers by exhibiting less anger when something goes wrong in the laboratory classrooms. It probably means that Thai physical chemistry teachers are quite patient while they are interacting to students.

Table 8. *Pre and Post Actual Means and Differences on Scales of the QTI.*

	Pre Actual	Post Actual	Difference (Post-Pre Actual)	*t* test
Leadership	19.94	20.07	0.13	0.30
Helping Friendly	19.55	19.01	-0.54	1.11
Understanding	19.76	19.74	-0.02	0.05
Student Resp./Freedom	13.58	12.88	-0.7	1.51
Uncertain	7.6	7.03	-0.57	0.93
Dissatisfied	9.10	8.40	-0.7	1.25
Admonishing	7.43	5.86	-1.57	2.60*
Strict	15.95	15.19	-0.76	1.28

*p<0.05, n=100

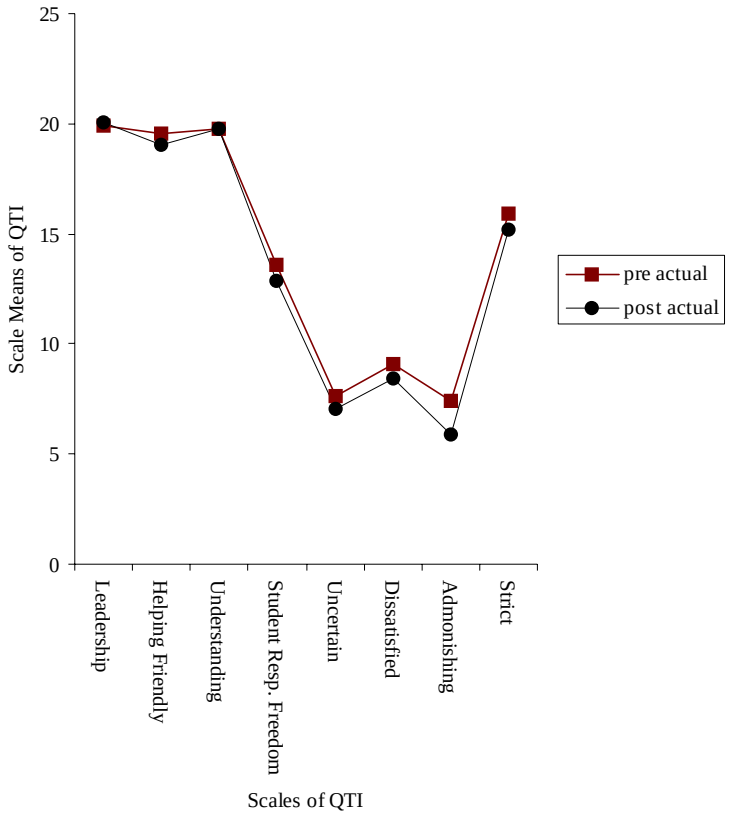


Figure 4: *Scale means for pre and post actual forms of the QTI.*

Students' attitudinal and cognitive achievements towards their subject of physical chemistry laboratory

The results of the attitude scores toward the physical chemistry laboratory are presented in Tables 9. The results in Table 9 obtained from the students were used to construct the graph shown in Figure 5.

Students' attitudes toward physical chemistry laboratory were gauged using the Attitude Scale. It was found that, for the whole sample, the post score of attitude was 24.03 compared with a pre score of 22.03. Thus, on the whole, there was very little change in the students-attitudes.

Table 9. *Means and Differences of the Two Tests in Physical Chemistry Obtained from the Whole Sample.*

	Pretest	Posttest	Difference (Posttest-Pretest)	*t* test
Attitude test	22.03	24.03	2.00	4.76**
Cognitive test	11.70	12.70	1.00	2.20*

** $p<0.001$, *$p<0.05$, n = 100

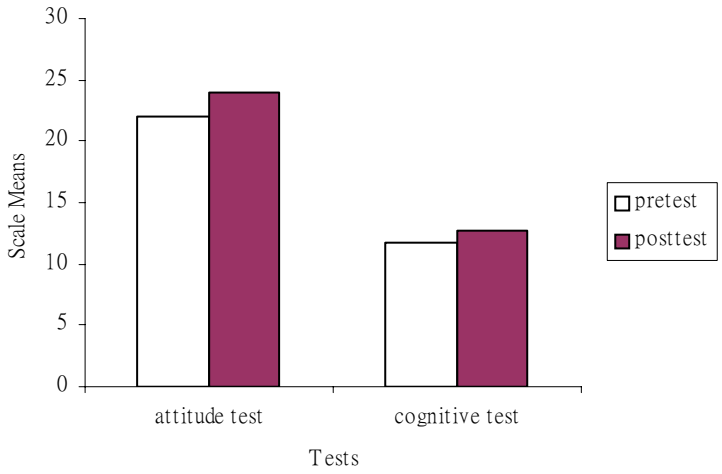


Figure 5: *The mean scores on the two tests in physical chemistry at the beginning and end of the semesters obtained from the whole sample.*

Associations between the students' perceptions of the classroom environment and student outcomes.

Table 10 shows the associations between the students' perceptions of the laboratory learning environment and a ten-item Attitude Scale based on the Test Of Science Related Attitudes (TOSRA) (Fisher, Henderson, & Fraser, 1995; Fraser, 1981) as measured by simple and multiple correlation. The simple correlation figures were statistically significant for the Student Cohesiveness, Open-Endedness and Material Environment scales, suggesting that student' attitudes were more likely to be positive where students perceived greater student cohesiveness, open-endedness and material environment. Furthermore, the beta weight (β) which indicates the association between an outcome and a particular scale when other scales

are controlled, reveals two statistically significant results (p<0.05) for the Open-Endedness and Material Environment scales. Both these scales were positively associated with the attitude scores when other CLEI scales were controlled. These findings were similar to previous study of Quek, Wong and Fraser (2001). According to the R^2 figure, it indicated that there was 12% of the variance predicted in students' attitudes that they perceived their laboratory learning environments.

Table 10. *Simple Correlation (r) and Multiple Regression (β) for Associations Between Students' Attitude and CLEI Scales.*

CLEI Scale	Attitude to Physical Chemistry Laboratory	
	r	*β*
Student Cohesiveness	0.20*	0.08
Open-Endedness	0.20*	0.21*
Integration	0.18	0.10
Rule Clarity	0.11	-0.08
Material Environment	0.25*	0.22*
Multiple Correlation, *R*		0.35*
R^2		0.12

*p<0.05, n = 100

For the associations between the classroom environment scales of the CLEI and students' cognitive achievement, the simple correlation was only statistically significant for the negative figure of the Rule Clarity scale, indicating that students' exam scores were lower where the students perceived stronger rule clarity. Additionally, the more conservative regression analysis showed that Rule Clarity still retained its significance when other CLEI scales were controlled. This was similar to a previous study of Henderson, Fisher, and Fraser (1995). The R^2 figure could not expect the variance in cognitive achievement considered to learning environment because the *R* value of 0.27 was not significant. The results are presented in Table 11.

Table 11. *Simple Correlation (r) and Multiple Regression (β) for Associations Between Student Cognitive Achievement and CLEI Scales.*

Scale	Cognitive Score	
	r	*β*
Student Cohesiveness	-0.13	-0.14
Open-Endedness	0.04	0.09
Integration	-0.05	0.11
Rule Clarity	-0.21*	-0.27*
Material Environment	0.01	0.15
Multiple Correlation, *R*		0.27
R^2		0.08

* p<0.05, ** p<0.01, n = 100

Associations between students' perceptions of their teacher's interpersonal behaviour and student outcomes

Table 12 shows the association data between interpersonal behaviour and a ten-item of Attitude Scale based on the Test Of Science Related Attitudes (TOSRA) (Fraser, 1981; Fisher, Henderson, & Fraser, 1995). The Leadership, Understanding scales were positively related to student attitudes, indicating that students' attitude scores were likely to be higher where teachers exhibited more leadership and understanding of students. However, there was no significant association between these two scales and the outcome in the regression analysis. These findings were broadly similar to the study of Wubbels, Brekelmans, and Hooymayers, (1991) and of Henderson, Fisher and Fraser (1994).

Table 12. *Simple Correlation (r) and Multiple Regression (β) for Associations Between Students' Attitude and QTI Scales*

Class Scale	Attitude to Physical Chemistry Laboratory	
	r	*β*
Leadership	0.20*	0.11
Helping/Friendly	0.14	- 0.05
Understanding	0.23*	0.20
Student Responsibility/Freedom	0.05	0.02
Uncertain	-0.06	0.01
Dissatisfied	-0.05	0.05
Admonishing	-0.06	-0.04
Strict	-0.05	-0.08
Multiple Correlation, *R*		0.25
R^2		0.06

* $p<0.05$, n = 100

The Dissatisfied scale was negatively associated with the exam scores. This indicates that students' exam scores were lower where teacher enforced stronger dissatisfied behaviour in laboratory classrooms. The multiple regression analysis indicates that the Dissatisfied scale retained its significance when other QTI scales were controlled. This finding was similar to the previous study of Rickards (1998) using the QTI to Australian students. The variance of 10% in cognitive achievement was accounted by student learning environment perceptions according to the R^2 figure. The results are presented in Table 13.

Table 13. *Simple Correlation (r) and Multiple Regression (β) for the Associations Between Student Cognitive Achievement and QTI Scales*

Scale	Cognitive Score	
	r	*β*
Leadership	-0.01	-0.09
Helping/Friendly	0.08	0.08
Understanding	0.07	-0.03
Student Responsibility/Freedom	0.04	0.14
Uncertain	-0.08	0.14
Dissatisfied	-0.25*	-0.42*
Admonishing	-0.12	0.03
Strict	-0.05	0.07

Multiple Correlation, *R*	0.32*
R^2	0.10

* $p<0.05$ ** $p< 0.005$, n = 100

Summary and Implications

This research describes the validity and the reliability of 35-item CLEI (the Actual and Preferred Forms), 48-item QTI (the Actual and Ideal Forms) through the use of analyses..

The results from students' perceptions of classroom environments indicated that an improvement was found in the students' perception of their actual classroom environment in terms of student cohesiveness and open-endedness at the end of the semester. It suggests that Thai physical chemistry teachers should attempt to improve the open-endedness of activities because there were little opened-end opportunities in laboratory sessions. In the mean time, the high cohesion of the students should be maintained in the laboratory classrooms. Also, students' perceptions of teacher-student interactions revealed that students agreed that the teachers actually interacted with students at the end of the semester with a level of admonishing behaviour lower than that at the beginning of the semester. This suggests that Thai physical chemistry teachers might decrease the level of admonishing behaviour. This way, the quality of teaching might be enhanced in the future.

Regarding to mean scores of the attitudinal and cognitive tests in physical chemistry, although significant improvement on pretest and posttest in physical chemistry were found in only two classes on each test, students were able to improve their achievement outcomes with significance.

In terms of student attitudes in physical chemistry laboratory, attitudinal outcomes were positively associated with the Student Cohesiveness, Open-Endedness and Material Environment scales. Furthermore, the Open-Endedness and Material Environment scale were significantly positive in regression analysis. Also, negative association between the Rule Clarity scale and cognitive achievement was found, and the Rule Clarity scale conserved its significance in the result of regression analysis. This indicated that Thai physical chemistry teachers should use their knowledge of classroom environments to bring about improvement of achievement outcomes and attitudes to students. College of education (1996) also suggested that Thai science teachers should recognize the importance of the classroom environment while teaching their students.

With teacher-student interactions, attitudinal outcomes positively associated with the Leadership and Understanding scales. The regression analysis showed that significance association between two scales and outcomes was not found. However, negative association between the Dissatisfied scale and cognitive achievement was found. Furthermore, the Dissatisfied scale still continuously contributed to outcomes in the result of regression analysis. This should be underlined that Thai physical chemistry teachers should give more attention to their interpersonal behaviour with their students. This might result in higher achievement in students.

Teachers can use these two questionnaires to improve classroom environments and the teacher-student interactions. The questionnaires could be used as a focus for reflection and discussion by teachers in classrooms.

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